S. HRG. 110–1236

EXAMINING THREATS AND PROTECTIONS FOR THE POLAR BEAR

HEARING

BEFORE THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

JANUARY 30, 2008

Printed for the use of the Committee on Environment and Public Works

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ONE HUNDRED TENTH CONGRESS
FIRST SESSION

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EXAMINING THREATS AND PROTECTIONS FOR THE POLAR BEAR

WEDNESDAY, JANUARY 30, 2008

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, DC.

The full committee met, pursuant to notice, at 10 a.m. in room 406, Dirksen Senate Office Building, Hon. Barbara Boxer (chairman of the full committee) presiding.

Present: Senators Boxer, Inhofe, Lieberman, Lautenberg, Klobuchar, Warner, Barrasso, Craig.

OPENING STATEMENT OF HON. BARBARA BOXER, U.S. SENATOR FROM THE STATE OF CALIFORNIA

Senator BOXER. Good morning, everyone. Very happy to be here with my distinguished Ranking Member, Senator Inhofe, my friend. We don't agree on everything, but we are good friends.

The Committee today is going to examine threats and protections for one of the most magnificent creatures in the world, the polar bear. I am just going to show a couple of charts, just how beautiful this creature is, and the next one as well, which shows the mama bear. Let's just put that up there for a minute.

There are an estimated 20,000 to 25,000 polar bears in 19 populations in the Arctic. But scientists are greatly concerned about their future, due to global warming and melting sea ice, which they depend on to hunt and den. So I am going to show a picture, this is the denning that goes on in the ice. Also, we have a picture of the polar bear getting ready to hunt its prey, standing on the ice and getting the necessary traction to make his or her move.

In December 2006, George W. Bush's Interior Secretary, our former Republican colleague and friend, Dirk Kempthorne, said "Polar bears' habitat may literally be melting." So I want to reiterate that. This is the Bush administration's Secretary of the Interior: "Polar bears' habitat may literally be melting." And then we are going to show you what this looks like when the ice begins to melt. If you look at the very top, that is what is left of the ice. We start in 1980, then 2005 and then 2007. You can see the shrinking of the ice.

It is a sad statement on the health of the planet when such a majestic species as the polar bear could be lost due to human activities. I view this as a moral issue, because I think the polar bear is one of God's most magnificent creatures. Thankfully, we have an important law to help protect imperiled species. It is called the Endangered Species Act, which helps preserve species and the places they live. For the polar bear, that includes the sea ice. As Secretary Kempthorne said, that sea ice is literally melting away.

However, in general, the Endangered Species Act and its protections begin when a species is listed as threatened or endangered. Unfortunately, this Administration, has utterly failed to do what it is supposed to do to save the polar bear. I look at today as a moment of truth: are they going to do it or not do it in time?

Unfortunately, we have seen the Administration fail to take other steps to combat global warming. This is just one.

Oversight is about accountability. It is about seeing whether any administration, Democratic, Republican, this one, the next one and the ones after that, whether they are living up to their obligations to the American people. I intend to continue to shine a spotlight on the Administration's actions.

Director Hall, on some things we certainly do agree. On January 17th, 2008 you said, "We need to do something about climate change, starting yesterday, and there needs to be a serious effort to look at greenhouse gases." But sir, with all due respect, you were also supposed to do something specific about the polar bear yesterday. In fact, you were obligated under the Endangered Species Act to list or withdraw your proposed listing for the polar bear by no later than January 9th, 2008.

The Fish and Wildlife Service got off to a slow start. It was only after being sued by conservation groups that it even began the process of considering whether to list the polar bear. And I want to thank those groups. Without you, we would be nowhere.

However, I find it curious that while our agency in the Interior Department is dragging its feet to list the polar bear, another agency in the Interior Department is moving quickly. The Minerals Management Service is charging full speed ahead to allow new oil and gas drilling activities in one of the biological hearts of the polar bear's domain, the Chukchi Sea, and we will show you the Chukchi Sea and the neighboring Beaufort Sea are home to nearly one-fifth of the world's polar bears.

Despite this, nearly 30 million acres of the Chukchi Sea will likely be opened to oil and gas leasing on February 6th. Had the polar been listed on the day it was supposed to have been listed, the MMS would have been required to consult with Fish and Wildlife Service. Because the listing is already long overdue, there should be no further delay. And I would like for you today to give us a firm commitment to take immediate action to protect the polar bear.

The American people want their grandchildren to share in the wonder of the polar bear. It is our moral obligation to protect God's creatures on earth. I look forward to hearing your testimony and that of the other witnesses, and I hope you will give us a really good surprise today. I hope you will say you are ready to do this listing before this lease starts, so that Fish and Wildlife can have input into this drilling.

Senator Inhofe.

[The prepared statement of Senator Boxer follows:]

STATEMENT OF HON. BARBARA BOXER, U.S. SENATOR FROM THE STATE OF CALIFORNIA

Today, this Committee examines threats and protections for one of the most magnificent creatures in the world: the polar bear. There are an estimated 20,000–25,000 polar bears in 19 populations in the Arctic. But scientists are greatly concerned about their future, due to global warming and melting sea ice, which they depend on to hunt and den.

As a matter of fact, in December 2006, George W. Bush's Interior Secretary, our former Republican colleague, Dirk Kempthorne said: "polar bears' habitat may literally be melting." These pictures help demonstrate this more than Secretary Kempthorne's or my words ever could. It is a sad statement on the health of the planet when such a majestic species as the polar bear could be lost due to human activities.

Thankfully, we have an important law to help protect imperiled species—the Endangered Species Act, which helps preserve species and the places they live. For the polar bear, that includes sea ice. And it is literally melting away. 11However, in general, the ESA and its protections begin when a species is "listed" as threatened or endangered. Unfortunately, this Administration has utterly failed to do what it is supposed to do to save the polar bear.

Just as it has failed to take the necessary steps to combat global warming. Oversight is about accountability; it is about seeing whether any Administration—Democratic or Republican—is living up to its obligations to the American people and I intend to continue to shine a spotlight on the Administration's actions.

Director Hall, on some things we agree. On January 17, 2008 you said: "We need to do something about climate change starting yesterday, and there needs to be a serious effort to look at greenhouse gases." But sir, with all due respect, you were also supposed to do something about the polar bear yesterday—in fact, you were obligated under the Endangered Species Act to list, or withdraw your proposed listing for the polar bear by no later than January 9, 2008.

The Fish and Wildlife Service got off to a slow start. It was only after being sued by conservation groups that it even began the process of considering whether to list the polar bear. However, I find it curious that while your agency in the Interior Department is dragging its feet to list the polar bear, another agency in the Interior Department—the Minerals Management Service is charging full speed ahead to allow new oil and gas drilling activities in one of biological hearts of the polar bear's domain—the Chukchi Sea.

The Chukchi Sea and the neighboring Beaufort Sea are home to nearly 1/5th of the world's polar bears. Despite this, nearly 30 million acres of the Chukchi Sea will likely be opened to oil and gas leasing on February 6th. Had the polar bear been listed on the date the Fish and Wildlife Service was obligated to list, the MMS would have been required to consult with the Fish and Wildlife Service.

Because this listing is already long overdue, there should be no further delay. I would like a firm commitment to take immediate action to protect the polar bear. The American people want their grandchildren to share in the wonder of the polar bear. It is our moral obligation to protect God's creatures on earth. I look forward to the testimony of the witnesses.

OPENING STATEMENT OF HON. JAMES M. INHOFE, U. S. SENATOR FROM THE STATE OF OKLAHOMA

Senator INHOFE. Thank you, Madam Chairman. Before I start my time, I have three things to put into the record. I note that Senator Stevens, from Alaska, has been very involved in this issue. He wanted to be here today, Madam Chairman, and could not do it. So without objection, I would like to have his statement in the record, and would encourage our colleagues to read it.

Along with that, the comments I received from the American Farm Federation and the Alaska Native Regional Corporation, all three in the record.

Senator BOXER. We will be happy to do that at your request, sir.

[The referenced statements from the American Farm Federation and the Alaska Native Regional Corporation was not submitted in time for print.]

[The referenced statement of Senator Stevens follows:]

Senator Ted Stevens
Statement for Senate Environment and Public Works Committee
"Examining Threats and Protections for the Polar Bear"
January 30, 2008

As a Senator for the State of Alaska for the past 39 years, I possess a deep professional and personal interest in the status of our wildlife. Wildlife provides basic subsistence for many of the approximately 120,000 native Alaskans. Consequently, Alaskans take great pride in the sustainable management of our natural resources.

The U.S. Fish and Wildlife Service's (USFWS) proposed listing of the polar bear as threatened under the Endangered Species Act (ESA) is unprecedented. None of the almost 1,900 previously listed species were occupying their entire geographic range at the time of listing, yet the polar bear is readily found throughout the Arctic.[1] None of the previously listed species had rising populations at the time of listing, yet the global population of polar bears has been steadily increasing for 40 years.[2] This proposed listing is unique because it is based on mathematical models as opposed to biological observations.

Although these models can be a useful scientific tool, I have deep concerns about how the USFWS used certain data in its decision making process. Most models assume that sea ice will continue to

[1] Servheen C (1990) The Status and Conservation of the Bears of the World. International Conference on Bear Research and Management Monograph Series No. 2. 32 pages.
[2] Maksimov LA, Sololov VK (1965) Polar bear: distribution and status of stocks; problems of conservation and research. pp 39-43 In: Proceedings First International Meeting on Polar Bear. University of Alaska.

melt over the next 100 years, but there is vast uncertainty as to how polar bears will respond to a changing climate[3]. In September 2007 the U.S. Geological Survey (USGS) released 9 technical reports on habitat changes, including sea ice decline, which may impact the polar bear population. These reports did not study the size of polar bear populations but examined sea ice decline models and the impact of sea ice decline on polar bear populations.

The key mathematical models in the reports are based on only five years of data. Three of the years were "good", meaning that sea ice coverage was normal and there was a high number of polar bear births, but USGS seized upon two bad years in 2004 and 2005, when the ice coverage declined slightly and birth rates were slightly lower, to create their pessimistic projections of polar bear numbers around the Arctic. The relatively small differences between the five years are not enough to make such drastic projections far into the future.

In the proposed rule, USFWS has favored one hypothesis and ignored contradictory data and theories. Polar bear experts at the Alaska Department of Fish and Game (ADFG) have shared with USFWS their observations of polar bears feeding on salmon, bearded seals, and other southerly-distributed species that have moved into areas where sea ice has receded. Considering the tremendous socio-economic impact of the proposed listing for the state of Alaska

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[3] Stempniewicz L (2006) Polar bear predatory behaviour toward molting barnacle geese and nesting glaucous gulls on Spitsbergen. Arctic 59: 247-251.

and our Nation, I am extremely concerned that USFWS failed to meaningfully consider other theories and information.

It appears that interest groups are clamoring for sea ice to be designated as critical habitat in order to end oil and gas exploration in the North Slope and curtail the use of fossil fuels throughout the country. This would only increase our reliance upon volatile, less environmentally sensitive foreign sources of oil and gas. Such a result would neither reduce greenhouse gas emissions, nor improve polar bear habitat. It is clear that the polar bear may be only the first in a long line of Arctic species to be the subject of a petition for listing under the ESA. My concern, as a Senator, is the crippling effect this will have on Alaskans, the national economy, as well as the ESA itself.

The polar bear is a vital resource for the 13,000 Alaskans who live on the North Slope. Polar bears are an important traditional food source for native Alaskans. Eskimo artisans may use polar bear body parts in handicrafts - further increasing the economic value of each polar bear. The polar bear harvest provides both sustenance and substantial economic benefits for these isolated northern communities. Unfortunately, listing the polar bear could provide the legal means for special interest groups to curtail subsistence hunting by native Alaskans, even though USFWS has stated that Alaskans are harvesting polar bears below the population's maximum sustainable yield.

Polar bears and energy development have co-existed in Alaska since oil was discovered in the Arctic in 1967. Under the Marine Mammal Protection Act, industry's activities have been closely monitored and permits have been issued to allow for incidental take. Existing regulations have been extremely effective - no polar bears have been killed by industry since the permitting process began.[4] Indeed, in *Range-wide Status Review of the Polar Bear,*[5] USFWS found there to be a negligible impact of oil and gas activities on the polar bear. Nonetheless, the proposed listing could subject oil and gas development in the North Slope to onerous, if not devastating regulatory oversight. *Center for Biological Diversity v. Kempthorne*[6] clearly illustrated the consequences that Alaskan industry can expect from the listing of the polar bear. Activities such as seismic exploration; sub-sea sediment sampling; construction and use of drilling structures; construction and use of roads, pipelines, runways and camps; well drilling; transportation of materials; and oil production and transportation could all be *presumed* to have harmful ecological consequences; and, therefore, the vast majority of industrial activities could require separate reviews with respect to the ecological consequences for polar bear denning, hunting, migration, and contaminant load, in addition to the consequences for species fed upon by the polar bear.

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[4] Schliebe S, Evans T, Johnson K, Roy M, Miller S, Hamilton C, Meehan R, Jahrsdoerfer S (2006) Range-wide status review of the polar bear (*Ursus maritimus*). US Fish and Wildlife Service Anchorage, AK.
[5] *Id.*
[6] *Center for Biological Diversity v. Kempthorne*, (filed Feb 13, 2006, N.D. California.).

Heightened regulatory burden on industry will depress oil and gas development. The State of Alaska receives well over $1 billion per year in the form of oil and gas revenue, which contribute to more than 50 percent to the State's annual operating budget. It is clear that an ESA listing could place Alaska's fiscal health in jeopardy.

Perhaps the most ironic aspect of the proposed listing is the potential for it to undermine the ESA - our nation's most celebrated tool for species conservation. Models of climate change predict that global biodiversity may decline by 35 percent by 2050.[7] Does this mean that we should list, in addition to the polar bear, the multitude of species that are currently abundant but may decline as a result of a changing climate? This is an unwarranted expansion in the interpretation of the ESA which could open the door for potential abuse of this law, to the detriment of species that would be affected by a weakened ESA and deviates from my original intent when I voted for this Act. The ESA, when used properly, is a tool to assist in the recovery of a species, but with the listing of the polar bear as threatened, the ESA would be used as a tool to curtail or eliminate the use of fossil fuels – not a goal of the ESA.

Even if the population of polar bears were to decline in response to melting sea ice, an ESA listing would not halt the loss of the bears' critical habitat. Arctic sea ice has been declined for the past 200

[7] Thomas CD, Cameron AC, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, Erasmus BF, De Siqueria MF, Grainger A, Hannah L, Hughes L, Huntley B, Van Jaarsveld AS, Midgley GF, Miles L, Ortega-Huerta MA, Peterson AT, Phillips OL, Williams SE (2004) Extinction risk from climate change. Nature 427: 145-148.

years - well before modern industrial activity.[8] Moreover, Dr. Syun-Ichi Akasofu of the International Arctic Research Center has found that the rate of melting has not changed despite recent increases in the concentration of carbon dioxide in the atmosphere.[9] Even if one were to accept the premise that Greenhouse Gases (GHG) are the main contributor to melting sea ice, the ESA cannot control the worldwide emission of GHGs. Regardless of whether the polar bear is listed as threatened, industrialization and deforestation in other nations will continue to add carbon dioxide to the atmosphere. Listing the polar bear as threatened in order to slow the melting of sea ice is a misguided effort and abuse of the ESA. Furthermore, it ignores the need to gain international support and coordination to address our changing climate. In the meantime, Alaskans would be needlessly subjected to severe economic and cultural consequences by agenda and publicity-driven special interest groups.

The ESA was created to provide the means to restore depleted species and their habitat. Not only does the proposed listing fail to address the fundamental problems causing a potential loss of polar bear sea ice habitat, but it threatens the rights and livelihoods of Alaskans. We must look for a better approach to protect Arctic wildlife.

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[8] Vinje (2001) Anomalies and trends of sea-ice extent and atmospheric circulation in the Nordic Seas during the period 1864-1998. Journal of Climate, 14:255-267.

[9] Akasofu SI (2006) Is the Earth still Recovering from the "Little Ice Age"? International Arctic Research Center University of Alaska Fairbanks.

Senator INHOFE. A lot has been said about the polar bear, the threats it allegedly faces and what should be done about it. In 2006, the United States Fish and Wildlife Service, under force of litigation, proposed to list the polar bear as a threatened species under the Endangered Species Act, based on concerns over retreating Arctic sea ice. The Service asserts that the reason for the decline in one or two bear populations is climate change. To make that assertion, they rely on hypothetical computer models showing massive loss of ice, including a recent U.S. Geological Survey modeling prediction that shrinking sea ice could eliminate two-thirds of the world's polar bears by 2050. Now, again, these are computer models which are constantly a problem.

This is a classic case of reality versus unproven computer models. I look forward to the testimony of Scott Armstrong, an Ivy League professor and the Nation's leading expert on forecasting methodology, who along with an Arctic climate change expert, authored a paper that challenges the USGS modeling.

The decision on whether or not to list the bear rests currently on computer models. Those models are invalid and any decision based on them is not justified.

Ironically, physical observation of the bear tells a much different story. The Fish and Wildlife Service estimates that there are currently, as the Chairman said in her opening statement, 20,000 to 25,000 polar bears. In the 1950's and 1960's, there were somewhere between 5,000 and 10,000 polar bears. So we are talking about an increase of somewhere between doubling and four times the number of polar bears there were just a few years ago. Canadian biologist, Dr. Mitchell Taylor, the director of wildlife research at the Arctic Government of Nunavut, dismisses these fears with evidence-based data on polar bear populations in Canada, where two-thirds of the world's bears reside.

Of the 13 polar bear populations out there, all but 2 are either growing or are stable. And the two I think are in the area, the western Hudson Bay area. A lot of that is due to regulations, hunting regulations that are being changed at this time. Just last month, researchers discovered an ancient polar bear jaw that dates back more than 100,000 years, to a time far warmer than it is at the present time. One award-winning geologist and professor from the University of Iceland said about the discovery, he said that "Despite the ongoing warming in the Arctic today, maybe we don't have to be quite so worried about the polar bear."

I would like to enter into the record actually three things. First of all a fact sheet that I have prepared with statements from biologists and wildlife scientists who have taken issue with the predictions of the demise of the polar bear. Also to put into the record separate statements from Dr. Susan Crockford, a Canadian evolutionary biologist and Dr. Matthew Cronin, a professor of animal genetics at the University of Alaska, Fairbanks.

Senator BOXER. We will be happy to put that in.

[The referenced fact sheet was not submitted at time of print.]

[The referenced statements of Susan Crockford and Matthew Cronin follows:]

STATEMENT OF SUSAN J. CROCKFORD, PH.D., EVOLUTIONARY BIOLOGIST/ ARCHAEOZOOLOGIST

What we know about polar bears is fundamentally incomplete. The nature of the beast and the habitat in which it lives combine to make the kind of scientific study that is routinely applied to other species virtually impossible. There is a profound uncertainty in polar bear evolutionary history, population numbers (both past and current), and details regarding most life history features, not to mention the uncertainties surrounding past, present and future conditions of its habitat. We also know very little about its primary prey, the ringed seal. In my opinion, these uncertainties are not adequately acknowledged in the hypothesis currently being used to predict a grim future for polar bear populations over the next few decades. I contend that we do not know nearly enough about polar bears or their environment to predict, with any degree of certainty, precisely how they will respond to a few degrees of warming.

What we do know, with absolute certainty, is that about 10,000 years ago the polar bear survived a period of significant warming that lasted about 2,000 years. During that time, temperatures in Arctic regions rose to at least 2.50C warmer than today and sea ice above western North America retreated much further in summer than it has even in the last few years. There is no evidence to suggest that sea ice disappeared entirely during this extended warm period or that polar bears disappeared; none of the ice-dependent prey species of polar bears, including ringed and bearded seals, disappeared either. Present numbers of polar bears are hard proof that the population which lived 8,000 years ago did not drop to catastrophic levels: indeed, the archaeological record of prehistoric peoples of the Arctic tells us that for the last 1,000 years at least, and probably much longer, polar bears, ringed seals and bearded seals were as well distributed across the North American arctic as they are today.

STATEMENT OF MATTHEW A. CRONIN, PH.D., PROFESSOR OF ANIMAL GENETICS AT THE UNIVERSITY OF ALASKA, FAIRBANKS

1. It is critical to separate science and management/policy. Science can tell us the status of wildlife populations, like polar bears, and make inference regarding the causes of impacts and predictions of change. The science presented on both sides of the polar bear issue is generally valid. The information presented by the field-experienced biologists in Alaska and Canada should be given special consideration because of their first-hand knowledge. This applies to all experienced biologists whether they agree or disagree with an ESA listing. However, science does not dictate policy. Science can help achieve a given policy but does not decide what the policy should be. Our elected representatives do.

2. Don't discredit scientists because of their funding source or because their interpretation of data doesn't agree with yours. This is prejudice. Be fair and judge science based on its merit. Blind acceptance or rejection is not acceptable in science.

3. The polar bear ESA listing is based on prediction, not the current status of the species worldwide. It is also based on apparent impacts to a limited number of populations. The science documenting population status, potential causative factors, and predicted future status has been done by qualified scientists and has credibility. So does work presenting alternatives.

4. It is critical to decide if the ESA is appropriate for a threat based on predictive models. Polar bears will be threatened with extinction if the climate, sea ice, and population model predictions are realized. The model results are legitimate predictions, but as predictions they should be considered hypotheses in need of testing with data in the future.

5. My opinion is that it is not appropriate to base an ESA decision on predictions. I would reserve the use of ESA to cases where threatened or endangered status is verified. If prediction is allowed as a standard for ESA, the number of species subject to ESA regulation will be limitless. Our entire natural resource industry and government management system will be overwhelmed with legal and regulatory burdens instead of focusing efforts on practical management in the field. Consider the extensive use of the ESA for groups that are not even species. Subspecies and populations (which are scientifically subjective designations) comprise more than 70 percent of the mammals and more than 50 percent of the birds listed in the U.S. Expanding the ESA to include populations that might be endangered in the future seems like a additional expansion beyond the intent and jurisdiction of the ESA.

6. The problem of human caused global warming should be explicitly dealt with as a specific issue. Use of the ESA for one species is not the proper way to deal with such a problem.

7. Please consider whether the polar bear ESA listing process has complied with Executive Order 13211 of 18 May 2001, which requires agencies to prepare "Statements of Energy Effects" for Federal actions.

8. Please seriously consider the proper role of the Federal Government as defined in the U.S. Constitution:

"The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people." (10th Amendment to the U.S. Constitution).

I believe that wildlife management is the role of states, not the Federal Government. I believe use of the InterState Commerce Clause of the Constitution to justify the ESA is contrived. Regardless, polar bears occur in only one State (Alaska) so this justification is not relevant in the case at hand. Dealing with global climate change directly is appropriate for the Federal Government. ESA listing of individual species is a distraction from this critical issue.

Thank you for your consideration.

Senator INHOFE. The fact is that the polar bear is simply a pawn in a much bigger game of chess. Listing the polar bear as a threatened species is not about protecting the bear, but about using the ESA to achieve global warming policy that special interest groups cannot otherwise achieve through the legislative process. These groups have made their agenda clear in comments filed with the Fish and Wildlife Service. Greenpeace and the Center for Biological Diversity urged the Service to force greenhouse gas-emitting projects, even those not in Alaska, to account for potential effects on the bear before they can go forward.

They wrote, "It is simply not possible to fully discuss the threat to the polar bear from global warming without regulatory mechanism to address greenhouse gas emissions." But the people who will suffer first under the ESA listing are the local indigenous people of Alaska and Canada. For example, Alaska's shipping and highway construction and fishing activities will have to be weighed against the bear.

Furthermore, the decision to list the polar bear would irreparably damage a culture. On January 14th, two groups representing the Canadian Inuit people asserted that "Environmental groups are using the polar bear for political reasons against the Bush administration over greenhouse gas emissions." That was a quote. According to the president, Mary Simon of ITK in Canada, "The polar bear is a very important subsistence, economic, cultural, conservation, management and rights concern. It is a complex, multi-level concern. But it seems the media, environmental groups and the public are looking at this in overly simplistic black and white terms."

I would like to enter a statement into the record and I look forward to the testimony of Richard Glenn, an Inupiaq Eskimo Naive from Alaska, who is a sea ice geologist and a subsistence hunter.

The bear is also being used as a tool to stop or slow natural resource development in Alaska. Last week of the House side, witnesses supporting the listing of the polar bear stated that no oil and gas leases should be allowed until the bear is listed, its critical habitat designated and a recovery plan put in place. As we know, that could take, judging from the past, a long, long time. We have species that have been on the ESA list for decades and still don't have a recovery plan.

Oil and gas—this is very significant—oil and gas exploration in Alaska accounts for 85 percent of the State's revenue and 25 percent of the Nation's domestic oil production. The price of crude oil is nearly $100 a barrel. Eliminating a quarter the U.S. production could be just absolutely devastating. I would have to ask the question of anyone who is testifying or anyone on this panel, are we concerned at all about the price of fuel, about the energy crisis we are under and about the possibility of eliminating 25 percent of our domestic production?

Thank you, Madam Chairman.

[The prepared statement of Senator Inhofe follows:]

STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Good morning. Much has been said about the polar bear, the threats it allegedly faces and what should be done about it. In 2006, the United States Fish and Wildlife Service, under force of litigation, proposed to list the polar bear as a threatened species under the Endangered Species Act based on concerns over retreating Arctic sea ice.

The Service asserts that the reason for a decline in one or two bear populations is climate change. To make that assertion, they rely on hypothetical computer models showing massive loss of ice, including a recent US Geological Survey modeling predicting that shrinking sea ice could eliminate 2/3 of the world's polar bears by 2050.

This is a classic case of reality versus unproven computer models. I look forward to the testimony of Scott Armstrong, an Ivy League professor and the nation's leading expert in forecasting methodology, who, along with an arctic climate change expert, authored a paper that challenges the USGS modeling. The decision on whether or not to list the bear rests entirely on computer models. If those models are invalid, then any decision based on them is not justifiable.

Ironically, physical observation of the bear tells a much different story. The Fish and Wildlife Service estimates that there are currently 20,000 to 25,000 polar bears. In the 1950's and 1960's, estimates were as low as 5,000–10,000 bears. Canadian biologist Dr. Mitchell Taylor, the director of wildlife research with the Arctic government of Nunavut, dismisses these fears with evidence based data on polar bear populations in Canada , where 2/3 of the world's bears reside. "Of the 13 populations of polar bears in Canada , 11 are stable or increasing in number. They are not going extinct, or even appear to be affected at present."

Just last month, researchers discovered an ancient polar bear jaw that dates back more than 100,000 years, to a time far warmer than the present. One award-winning geologist and professor from the University of Iceland said about the discovery "that despite the on-going warming in the Arctic today, maybe we don't have to be quite so worried about the polar bear." I would like to enter into the record a fact sheet I prepared with statements from biologists and wildlife scientists who have taken issue with the predictions of the demise of the polar bear. I would also like to put in the record separate statements from Dr. Susan Crockford a Canadian Evolutionary Biologist and Dr. Matthew Cronin a Professor of Animal Genetics at the University of Alaska Fairbanks .

The fact is that the polar bear is simply a pawn in a much bigger game of chess. Listing the bear as a threatened species is not about protecting the bear but about using the ESA to achieve global warming policy that special interest groups cannot otherwise achieve through the legislative process. These groups have made their agenda clear. In comments filed with the Fish and Wildlife Service, Greenpeace and the Center for Biological Diversity urged the Service to force greenhouse-gas-emitting projects, even those not in Alaska , to account for potential affects on the bear before they can go forward. They wrote, "It is simply not possible to fully discuss the threat to the polar bear from global warming without regulatory mechanisms to address greenhouse gas emissions."

But the people who will suffer first under an ESA listing are the local, indigenous people in Alaska and Canada . For example, Alaska 's shipping, highway construction and fishing activities will have to be weighed against the bear. Furthermore, the decision to list the polar would irreparably damage a culture. On January 14, two groups representing Canadian Inuit people asserted that environmental groups are "using the Polar Bear for political reasons against the Bush administration over greenhouse gas emissions." According to President Mary Simon of ITK in Canada , "The Polar Bear is a very important subsistence, economic, cultural, conservation, management, and rights concern. It's a complex and multilevel concern. But it seems the media, environmental groups, and the public are looking at this in overly simplistic black and white terms." I would like to enter the statement into the record and I look forward to the testimony of Richard Glenn, an Inupiaq Eskimo native from Alaska , who is a sea ice geologist and a subsistence hunter.

The bear is also being used as a tool to stop or slow natural resource development in Alaska . Last week, on the House side, witnesses supporting the listing of the polar bear stated that no oil and gas leases should be allowed until the bear is listed, its critical habitat designated and a recovery plan put in place. That could be a very long time. We have species that have been on the ESA list for decades and still don't have a recovery plan. Oil and gas exploration in Alaska accounts for 85 percent of the state's revenue and 25 percent of the nation's domestic oil production. The price of crude oil is nearing $100 a barrel. Eliminating a quarter of the US oil production will make us more dependent on foreign sources of oil, not less.

The bottom line is that the attempt to list the polar bear under the ESA is not based on any current polar bear decline but is founded entirely on computer climate models and predictions that are fraught with uncertainties. Unfortunately, the bear is being used as a back door to climate change regulation. I look forward to hearing from our witnesses.

Senator BOXER. Thanks, Senator.

The early bird rule applies, so we will go to Senator Lautenberg and then Senator Lieberman. Senator Lautenberg?

OPENING STATEMENT OF HON. FRANK LAUTENBERG, U. S. SENATOR FROM THE STATE OF NEW JERSEY

Senator LAUTENBERG. Thank you, Madam Chairman. I really appreciate the fact that you do take the leadership role in viewing and analyzing questions that are before us about in some ways the almost very existence of the world as we know it.

When I listen to our friend from Oklahoma, who is the skeptic here, about the things that we see in front of us, about computer modeling, I happen to have come out of the computer business, I spent only 30 years of my life there. But computer modeling is what we do when we send people up in space shuttles. We do a lot of computer modeling to see whether or not we are prepared to do that. We use it certainly in the military. We certainly use computer modeling in determining what kind of medication is going to be effective against various of the diseases and illnesses that man sees.

So with all due respect, Senator Inhofe's skepticism about the use of computer modeling certainly presents, as far as I am concerned, a serious challenge to what the world is right in front of our eyes.

We see the Bush administration valuing oil over our environmental protections for future generations. And when we hear about the price of oil and we think about what is causing oil prices to behave as they do, well, it is our friends in Saudi Arabia and places like that who are engaged in a conspiracy to raise prices to whatever they can extract from a dependent world. And the difference is not in Alaska. That is only a very small part of the whole thing. We in this Committee saw first-hand on our visit to Greenland global warming already significantly damaging our natural world. We saw green where there was recently complete ice coverage. We are seeing that melting trend repeat itself across the world.

I took the trouble to go to Antarctica and the South Pole half a dozen years ago and meet with the National Science Foundation and see what they were able to develop in terms of warnings about ice melt. Now we see that pace accelerating. The Arctic Ocean, for example, could be devoid of ice in the summertime by 2040, according to the latest science. Since polar bears are totally dependent on sea ice to live, hunt, breed, two-thirds of the world's polar bears are on a path toward extinction. It is a sign of things to come. It is not only a precious species, but a harbinger of what the future might look like. According to the U.S. Geological Survey, as the sea ice goes, so goes the polar bear.

As most people in the room know, polar bears have been in trouble for a long time. Between 1981 and 2004, the average female polar bear's weight dropped from 650 pounds to 510 pounds. That is a substantial difference in the ability of the species to adjust. During a similar period, an average polar bear litter shrunk by 15 percent.

Science alone makes it clear that the polar bear should be considered a threatened species and should be protected. But our concerns are not limited to the polar bear. It is one of the more visible examples of the toll that global warming is taking on our whole ecosystem. Our world is changing. But instead of listening to science, the Bush administration is more concerned with satisfying the oil industry.

This month, despite the science, the Administration announced that it needed more time to determine whether or not to protect the dying polar bear. At the same time, the Administration announced that it would allow companies to drill in the same habitat where polar bears currently live. And I find it hard to believe that delaying the polar bear decision so that it occurs after the oil drilling was not simply a coincidence. To me there is no clearer example than this of the Administration valuing oil over existence, over life. Science has proven that the polar bear is threatened, and instead of acting swiftly to protect it, the Administration is promoting the interests of the oil companies.

Madam Chairman, it is wrong. Global warming is the biggest environmental threat our world and human existence faces. It threatens our food supply, the air we breathe, and the well-being of future generations. If we continue down this path as we are, we endanger the existence of countless species and ignore our planet's cry for help. When we saw here an example of the change in the ecology here in the neighborhood, in the Potomac River, when male fish carried female eggs, doesn't that tell us all something, that this world is on a path toward, if not reshaping, perhaps lack of existence? We dare not wait any longer for our children and grandchildren and potentially mankind. We must take bold and aggressive action to reduce greenhouse gases. I am glad that this Committee and our colleagues have taken this step to do just that.

Thank you, Madam Chairman.

Senator BOXER. Thank you so much, Senator.

Before I call on Senator Barrasso, then we will go to Senator Lieberman and Senator Craig, I wanted to place a couple of things in the record to compete with what Senator Inhofe put in the record. A 2007 USGS study, scientists conclude that by 2050, two-thirds of all polar bears could be lost if we don't take protective action. Then the World Conservation Union report of 2006, some of the premier scientists in the world and experts from this organization say the polar bear is threatened. These are peer-reviewed articles, so they will appear in the record following the articles put in by my esteemed Ranking Member.

[The referenced World Conservation Union report of 2006 was not submitted at time of print.]

[The referenced 2007 USGS study follows.]

USGS
science for a changing world

USGS Science Strategy to Support U.S. Fish and Wildlife Service Polar Bear Listing Decision

Forecasting the Range-wide Status of Polar Bears at Selected Times in the 21st Century

By Steven C. Amstrup[1], Bruce G. Marcot[2], and David C. Douglas[3]

Administrative Report

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
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Abbreviations, Acronyms, and Symbols

Abbreviations, Acronyms, and Symbols	Meaning
AR-4	IPCC Fourth Assessment Report
BB	Baffin Bay IUCN polar bear subpopulation unit
BN	Bayesian Network
BS	Barents Sea IUCN polar bear subpopulation unit
CS	Chukchi Sea IUCN polar bear subpopulation unit
DS	Davis Strait IUCN polar bear subpopulation unit
EG	East Greenland IUCN polar bear subpopulation unit
FB	Foxe Basin IUCN polar bear subpopulation unit
GB	Gulf of Boothia IUCN polar bear subpopulation unit
GCM	General Circulation Model
HADISST	Hadley Center sea ice and temperature data set
IBCAO	International Bathymetric Chart of the Arctic Ocean
IPCC	International Panel on Climate Change
IUCN	International Union for the Conservation of Nature
KB	Kane Basin IUCN polar bear subpopulation unit
KS	Kara Sea IUCN polar bear subpopulation unit
LS	Lancaster Sound IUCN polar bear subpopulation unit
LVS	Laptev Sea IUCN polar bear subpopulation unit
MC	M'Clintock Channel IUCN polar bear subpopulation unit
NASA	National Space and Aeronautics Administration
NBS	Northern Beaufort IUCN polar bear subpopulation unit
NW	Norwegian Bay IUCN polar bear subpopulation unit
PBSG	Polar Bear Specialists Group
PMW	Passive Microwave
QE	Queen Elizabeth Islands IUCN polar bear subpopulation unit
RSF	Resource Selection Function
SBS	Southern Beaufort Sea IUCN polar bear subpopulation unit
SHB	Southern Hudson Bay IUCN polar bear subpopulation unit
SRES	Special Report on Emissions Scenarios
SRES A1B	SRES, greenhouse gas forcing scenario that assumes "business as usual"
USFWS	U.S. Fish & Wildlife Service
VM	Viscount Melville Sound IUCN polar bear subpopulation unit
WHB	Western Hudson Bay IUCN polar bear subpopulation unit

Forecasting the Range-wide Status of Polar Bears at Selected Times in the 21st Century

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Abstract

To inform the U.S. Fish and Wildlife Service decision, whether or not to list polar bears as threatened under the Endangered Species Act (ESA), we forecast the status of the world's polar bear (*Ursus maritimus*) populations 45, 75 and 100 years into the future. We applied the best available information about predicted changes in sea ice in the 21st century to current knowledge of polar bear populations and their ecological relationships to the sea ice to understand how the range-wide population of polar bears might change. We combined the world's 19 polar bear subpopulations into 4 ecological regions based on current and projected sea ice conditions. These "ecoregions" are the (1) Seasonal Ice Ecoregion which includes Hudson Bay, and occurs mainly at the southern extreme of the polar bear range, (2) the Archipelago Ecoregion of the Canadian Arctic, (3) the Polar Basin Divergent Ecoregion where ice is formed and then advected away from near-shore areas, and (4) the Polar Basin Convergent Ecoregion where sea ice formed elsewhere tends to collect against the shore. We incorporated projections of future sea ice in each ecoregion, based on 10 general circulation models (GCMs), into two models of polar bear habitat and potential population response. First, we used a deterministic model of past, current, and future polar bear carrying capacity which assumed a linear relationship between bear density and annual average sea ice extent. Because this approach did not include seasonal changes in ice availability or other possible population stressors, it provided an optimistic view of the potential magnitude of and change in population carrying capacity by ecoregion and time step. Second, we developed a Bayesian network (BN) model structured around population stressors that could affect the factors considered in ESA decisions. The BN model combined empirical data, interpretations of data, and professional judgment into a probabilistic framework. Although BN models can be based on the collective judgment of multiple experts, time constraints in this project allowed input from only one expert. Therefore, we consider our BN model a prototype, and we provide guidance regarding next steps necessary to further refine the model. The BN model incorporated information about annual and seasonal sea ice trends as well as potential effects of other population stressors such has harvest, disease, predation, and effects of increasing human activity in the north due to ice retreat. Under both modeling approaches, polar bear populations were forecasted to decline throughout all of their range during the 21st century. In projections based upon ensemble mean ice predictions, the carrying capacity model forecasted potential extirpation of polar bears in the Polar Basin Divergent Ecoregion in 75 years. Projections using minimal ice levels forecasted potential extirpation in this ecoregion by year 45, whereas projections using maximal ice levels forecasted steady declines but not extirpation by year 100. Populations of polar bears in the other ecoregions were projected to decline at all time steps, with severity of decline dependent upon whether minimum, maximum or mean ice projections were used. Dominant outcomes of the BN model were for extinction of polar bear populations in the Seasonal Ice

and Polar Basin Divergent Ecoregions by 45 years from present, and in the Polar Basin Convergent Ecoregion by 75 years from present. The BN model projected high non-zero probabilities that Archipelago polar bears could occur at smaller numbers than now through the end of the century. Declines in ice habitat were the overriding factors determining all model outcomes. Although management of human activities could forestall extinction in the Archipelago and Polar Basin Convergent ecoregions, it could not qualitatively alter the prognosis of extinction for the Polar Basin Divergent and Seasonal Ecoregions. Similarly, model results indicated that sea ice conditions would have to be substantially better than even the most conservative GCM projections to result in a qualitatively different outcome for any of the ecoregions. Our modeling suggests that realization of the sea ice future which is currently projected, would mean loss of $\approx 2/3$ of the world's current polar bear population by mid-century.

Introduction

Study Objective

Polar bears depend upon sea ice for access to their prey and for other aspects of their life history (Stirling and Øritsland 1995; Stirling and Lunn 1997; Amstrup 2003). Observed declines in sea ice availability have been associated with reduced body condition, reproduction, survival, and population size for polar bears in parts of their range (Stirling et al. 1999; Obbard et al. 2006; Stirling and Parkinson 2006; Regehr et al. 2007b). Observed (Comiso 2006) and projected (Holland et al. 2006) sea ice declines have led to the hypothesis that the future welfare of polar bears range-wide may be diminished, and to the U.S. Fish and Wildlife Service (FWS) proposal to list the polar bear as a threatened species under the Endangered Species Act (U.S. Fish and Wildlife Service 2007). The classification as a "threatened species" requires determination that it is likely the polar bear will become an endangered species within the "foreseeable future" throughout all or a significant portion of its range. An "endangered species" is any species that is in danger of extinction throughout all or a significant portion of its range. To help inform the final listing decision, the FWS requested that the U.S. Geological Survey (USGS) conduct additional analyses of polar bears and their sea ice habitats. Between February and August 2007, USGS and collaborators developed nine reports targeting specific questions considered especially informative to the final decision. This report, one of the nine, builds upon the other eight reports and uses other current information on polar bears to forecast the status of polar bears occurring in different parts of the Arctic at three future periods in the 21^{st}-century.

We use the best available information and knowledge, including that derived from new studies requested by the FWS, to forecast the future status of polar bears in each of 4 ecoregions (Figure 1). We present our forecast in a "compared to now" setting where projections for the decade of 2045-2055, 2070-2080, and 2090-2100 are compared to the "present" period of 1996-2006. For added perspective we also look back to the decade of 1985-1995. Hence, we examined five time periods in total. Our view of the present and past are based on sea ice conditions derived from satellite data. Our future forecasts are based largely on information derived from general circulation model (GCM) projections of the extent and spatiotemporal distribution of sea ice.

Background biology

Polar bears occur throughout portions of the Northern Hemisphere where the sea is ice-covered for all or much of the year. Polar bear genetics indicate that the species branched off from brown bears (*Ursus arctos*) and invaded an open niche on the surface of the sea ice during maximal extent of the continental ice sheets in the very late Pleistocene. Molecular genetic techniques suggest this could have occurred as long ago as 250,000 years (Amstrup 2003).Very few polar bear fossils are known, however, and those that have been discovered are relatively recent. They appear for the first time in the fossil record only 40 to 50 thousand years ago (Thenius 1953; Kurtén 1964). During their short evolutionary history, polar bears have diverged substantially from brown bears, apparently under selective pressures stemming from their specialization for capturing seals from the surface of the ice. Stanley (1979) described the many recently-evolved traits of polar bears as an example of "quantum speciation." The dearth of polar bear fossils reflects their specialty of living on the sea ice. Remains of dead animals on the sea ice would tend to accumulate on the sea floor rather than on land where they are more accessible to human discovery.

Since moving offshore, behavioral and physical adaptations have allowed polar bears to increasingly specialize at hunting seals from the surface of the ice (Stirling 1974; Smith 1980; Stirling and Øritsland 1995). Polar bears derive essentially all of their sustenance from marine mammal prey and have evolved a strategy designed to take advantage of the high fat content of marine mammals (Best 1984). Over half of the calories in a seal carcass are located in the layer of fat between the skin and underlying muscle (Stirling and McEwan 1975). Polar bears show their preference for fat by quickly removing the fat layer from beneath the skin after they catch a seal. The high fat intake that can be achieved by specializing on marine mammal prey has allowed polar bears to thrive in the harsh Arctic environment and to become the largest of the extant Ursids (Stirling and Derocher 1990; Amstrup 2003).

Over much of their range, polar bears are dependent on one species of seal, the ringed seal (*Phoca hispida*). Polar bears occasionally catch belugas (*Delphinapterus leucas*), narwhals (*Monodon monocerus*), walrus (*Odobenus rosmarus*), and harbor seals (*P. vitulina*) (Smith 1985; Calvert and Stirling 1990; Smith and Sjare 1990; Stirling and Øritsland 1995; Derocher et al. 2002). Walruses can be seasonally important in some parts of the polar bear range (Parovshchikov 1964; Ovsyanikov 1996). Bearded seals (*Erignathus barbatus*) can be a large part of their diet where they are common and are probably the second most common prey of polar bears (Derocher et al. 2002). Throughout most of their range, however, polar bears are most dependent upon ringed seals (Smith and Stirling 1975; Smith 1980). The relationship between ringed seals and polar bears is so close that the abundance of ringed seals in some areas appears to regulate the density of polar bears, while polar bear predation in turn, regulates density and reproductive success of ringed seals (Hammill and Smith 1991; Stirling and Øritsland 1995). Across much of the polar bear range, their dependence on ringed seals is close enough that the abundances of ringed seals can be estimated by knowing the abundances of polar bears (Stirling and Øritsland 1995; Kingsley 1998).

Polar bears rarely can catch seals on land or in open water (Furnell and Oolooyuk 1980); rather, they consistently catch seals and other marine mammals only at the air-ice-water interface. This dependence of polar bears on hunting at the ice surface, where aquatic mammals must come to breathe, is evident in the behavior of ringed seals. Steady predation pressure from polar bears over thousands of years has led ringed seals to use subnivian (below the snow) birthing lairs and to interrupt spring and summer basking with frequent periods of scanning their surroundings for bears. This is in contrast with Weddell seals (*Leptonychotes weddelli*), the southern hemisphere equivalent of ringed seals, which bask and give birth in the open (Stirling 1977) and can be approached by humans without reaction.

Although there are local exceptions, it appears that polar bears gain little overall benefit from alternate foods. Even in Hudson Bay where polar bears are forced onto land for extended periods with access to a variety of foods including human refuse, little terrestrial food is incorporated into polar bear tissues (Ramsay and Hobson 1991). In short, maintenance of polar bear populations is dependent upon marine prey, largely ringed seals, and they are tied to the surface of the ice for effective access to those prey.

Polar bears occur in most ice-covered regions of the northern hemisphere, including the center of the polar basin (Stefansson 1921). They are not evenly dispersed throughout this area, however. Polar bears have been observed most frequently in shallow-water areas near shore and in other areas where currents and upwellings keep the winter ice cover from becoming too solidified. These shore leads and polynyas create a zone of active unconsolidated sea ice that is small in geographic area but contributes ~50% of the total productivity in Arctic waters (Sakshaug 2004). Polar bears, are most commonly observed in or near these near shore zones where ice is constantly moving, opening up and reconsolidating, rather than pelagic areas which are of lower productivity (Stirling and Smith 1975; Pomeroy 1997; Stirling 1997), and have been shown to focus their annual activity areas over these regions (Stirling et al. 1981; Amstrup and DeMaster 1988; Stirling 1990; Stirling and Øritsland 1995; Stirling and Lunn 1997; Amstrup et al. 2000, 2004a, 2005). Not surprisingly, ice over shallow waters less than 300m deep has now been shown to be the most preferred habitat of polar bears throughout the polar basin (Durner et al. 2007).

Given their wide geographic distribution, polar bears inhabit regions with very different sea ice conditions. The southern reaches of their range includes areas where sea ice is seasonal. There, polar bears are forced onto land where they are food deprived for extended periods each year. Polar bears of Hudson Bay are the best known example of this situation, but bears in Foxe Basin, Davis Strait, and Baffin Bay also are "stuck" on land for a portion of the year when the sea ice in their area melts entirely. Other polar bears live in some of the harshest and most northerly climes of the world where the ocean is ice-covered year-round. This includes northerly regions of the Canadian Arctic archipelago and northern Greenland (Jonkel et al. 1976). Others live in the pelagic regions of the polar basin where there are strong seasonal changes in the character of the ice. There polar bears historically have remained on the advancing and retreating ice pack throughout the year, despite the sometimes very long seasonal movements required to do so (Amstrup 1986; Amstrup and DeMaster 1988; Amstrup et al. 2000). For example, sea-ice extends as much as 400 km south of the Bering Strait that separates Asia from North America, and polar bears extend their range to the southernmost extreme of the ice (Ray 1971). Because sea ice disappears from most of the Bering and Chukchi seas in summer, however, polar bears occupying these areas must move as far as 1000 km northward to stay on the retreating ice (Garner et al. 1990, 1994). In the Chukchi Sea and elsewhere, polar bears spend their summers concentrated along the edge of the persistent pack ice. Significant northerly and southerly movements appear to be dependent upon seasonal melting and refreezing of ice near shore (Amstrup et al. 2000).

Telemetry data have shown that polar bears do not wander aimlessly on the ice, nor are they carried passively with the ocean currents as previously thought (Pedersen 1945). Rather, they occupy multi-annual activity areas from which they seldom leave. Tracking data show that polar bears use seasonally preferred or "core" regions every year, despite variation in annual activity area boundaries (Amstrup et al. 2000, 2001, 2004a, 2005). This suggests that activity areas of polar bears, when viewed over multi-year periods, could be called home ranges. All areas of the home range, however, will not be used each year. Sea-ice habitat quality varies temporally as well as geographically (Stirling and Smith 1975; DeMaster et al. 1980; Ferguson et al. 1997, 1998, 2000a, 2000b; Amstrup et al. 2000). In areas where sea ice cover and character are seasonally dynamic, a large multi-year home range, of which only a portion may be used in any one season or year is an important part of the polar bear life history strategy. In other regions where ice is less dynamic, smaller and less variable activity areas are common (Messier et al. 1992; Ferguson et al. 2001).

The seasonal movement patterns of polar bears serve to emphasize the role of sea-ice in their life cycle. In the Beaufort Sea, the largest monthly activity areas and highest movement rates are during June-July and November-December. This matches the temporal patterns of ice melt and freeze in the area (Gloersen et al. 1992). Polar bears catch seals mainly by still-hunting (Stirling and Latour 1978). The dynamic summer and autumn ice must minimize predictability of seal hunting opportunity. Unpredictable ice distributions could require longer bear movements and larger bear activity areas during freeze-up and break-up. From May-August, measured net monthly movements of polar bears in the Beaufort Sea were significantly to the north for all bears, and in October they moved back to the south (Stirling 1990; Amstrup et al. 2000). October has historically been the month of freeze-up in the southern Beaufort Sea. In recent years, especially, October has been the first time in months when ice is available over the shallow water near-shore. Polar bears summering on the persistent pack ice quickly move into shallow water areas as soon as new ice forms in autumn, and they disperse easterly and westerly along near shore unconsolidated ice zones during winter. Mauritzen et al. (2001, 2002) also found movement patterns that were closely tied to seasonal ice cycles in other parts of the polar basin. Polar bears, in fact, have adapted their movement strategies to accommodate a broad range of sea ice characteristics (Messier et al. 1992; Ferguson et al. 1997, 1999).

The common denominator is that polar bears make seasonal movements to maximize their foraging time on sea ice that is suitable for hunting (Amstrup 2003). Polar bears appear to require relatively high concentrations of sea ice for effective hunting. Recent observations indicate that during most of the year, these preferred hunting habitats are sea-ice areas where the ice cover is ≥50% . (Stirling et al. 1999; Durner et al. 2004, 2006, 2007).

Methods

We took two approaches to forecast how the future range-wide population of polar bears might be different than it is now. Our first method provided estimates of the maximum potential sizes of polar bear populations based on climate modeling projections of the quantity of their habitat — but in the absence of effects of any additional stressors or knowledge about changes in habitat distribution. Our second method provided estimates of how the presence of multiple stressors, including changes in the quantity of sea ice as well as its spatiotemporal distribution, may affect polar bears.

The first approach was a deterministic calculation of polar bear habitat amount and carrying capacity in each ecoregion. We used estimated numbers of polar bears currently occupying each of the world's subpopulations, and the amount of sea-ice habitat currently in each area, to estimate the present-day polar bear density in each of 4 defined ecoregions (Figure 1). Then we multiplied the densities by the projected future (or empirically determined historic) amount of polar bear habitat in each ecoregion at various time periods, to derive the maximum potential number of bears that habitat could support. This is an estimate of polar bear carrying capacity, given the assumptions that current populations are at or near carrying capacity, that polar bear densities (number of bears per unit area) do not change, and that quality of the future habitat is equivalent to that at present. Of course, we recognize that such calculations oversimplify the eventuality. Yet, these simple calculations provide approximate numerical references of polar bear numbers that help place other discussions of future change into perspective.

Our second approach, a Bayesian network (BN) population stressor model, addressed many shortcomings of the carrying capacity model by incorporating probabilistic calculations of potential effects from multiple stressors on polar bear populations. The BN model used the same projections of habitat change as in the carrying capacity model, but it also included seasonal habitat changes as well as anticipated likelihoods of changes in several other stressors (Figure 2). The BN model accommodated scenarios of whether availability of food for polar bears would likely change and whether bears might redistribute themselves because of changes in habitat. Also considered was whether changes in hunting, oil and gas development, contaminants, parasites, disease agents and other potential anthropogenic (human-caused) stressors could become more or less influential than they are now. The BN model parameterized knowledge about the effects of observed habitat changes on polar bear distribution, demography and physical condition. This included understandings gained from other studies by the USGS relative to the listing decision, and expert judgment on the effects of a variety of other factors which might alter the future for polar bears. Construction of the BN model allowed us to integrate qualitative judgments, regarding how polar bears interact with their environment, with quantitative habitat predictions in a synthetic model to provide relative probabilities of potential future outcomes. Forecasts of the future status of polar bears were based on comparisons between current and future sea ice, and on other salient changes in the polar bear's environment that may change as the ice diminishes. Current ice conditions were extracted from data sets derived from passive microwave satellite imagery, 1979 – 2006 (*http://nsidc.org/data/nsidc-0051.html*). Future ice conditions were extracted from GCM projections (https://esg.llnl.gov:8443). In addition to sea ice extent and distribution data from satellite images and GCMs, we used resource selection functions (RSFs) to identify preferred, optimal polar bear habitat. The RSFs allowed us to evaluate whether preferred sea ice habitats may change at different rates than the overall sea ice cover.

We made forecasts of the future for polar bears in each of four ecoregions. We defined the ecoregions based on observed and GCM-projected differences in sea ice, and how polar bears respond or may respond to those changes. In the following section, we provide detailed descriptions of the four polar bear ecoregions. Next, we describe the process we used to make projections of the amount and distribution of future sea ice habitat. Finally we provide details of the modeling methods we used to project the future status of polar bears.

Polar Bear Ecoregions

Polar bears are distributed throughout regions of the Arctic and subarctic where the sea is ice covered for large portions of the year. Although movements of individual polar bears overlap extensively, telemetry studies have demonstrated spatial segregation among groups or stocks of polar bears in different regions of their circumpolar range (Schweinsburg and Lee 1982; Amstrup 1986, 2000; Garner et al. 1990, 1994; Messier et al. 1992; Amstrup and Gardner 1994; Ferguson et al. 1999; Carmack and Chapman 2003). Patterns in spatial segregation suggested by telemetry data, along with information from survey and reconnaissance, marking and tagging studies, and traditional knowledge, have resulted in recognition of 19 partially discrete polar bear groups (Aars et al. 2006). There is considerable overlap in areas occupied by members of these groups (Amstrup et al. 2004a, 2005), and boundaries separating the groups are adjusted as new data are collected. Nonetheless, these boundaries are thought to be ecologically meaningful, and the 19 units they describe and are managed as subpopulations (Figure 1).

In this report, we adhere largely to these group designations as they are used by International Union for the Conservation of Nature (IUCN) Polar Bear Specialist Group (PBSG) described in Aars et al. (2006). Our descriptions digress somewhat from those of the PBSG in regions of the polar basin where current knowledge of sea ice conditions and polar bear habitat preferences suggest that digression makes sense. We first redefined a Queen Elizabeth Islands subpopulation (QE). This subpopulation had historically been identified for the continental shelf region and inter-island channels between Prince Patrick Island and the northeast corner of Ellesmere Island. This unit was originally a geographic catchall population to account for the remainder of northern Canada (Aars et al. 2006). This area is characterized by heavy multi-year (old age) ice, except for a recurring lead system that runs along the Queen Elizabeth Islands from the northeastern Beaufort Sea to northern Greenland (Stirling 1980). Approximately 200 polar bears could be resident here and some bears from other regions have been recorded moving through the area (Durner and Amstrup 1995; Lunn et al. 1995). In 2003, the Canadian Polar Bear Technical Committee and the Canadian Polar Bear Administrative Committee agreed not to identify the QE subpopulation. Rather, they concluded it should be included as an undifferentiated portion of the central Arctic Basin (Lunn et al. 2006, page 101). Here, we reinstated QE as an important ecological unit. We also formally extended the QE boundary to include northern Greenland, based upon observed and predicted behavior of sea ice. Like the Northern Beaufort Sea subpopulation, QE occurs in a region of the polar basin that recruits ice as it is advected from other portions of the polar basin (Comiso 2002; Rigor and Wallace 2004; Belchansky et al. 2005; Holland et al. 2006; Durner et al. 2007; Ogi and Wallace 2007; Serreze et al. 2007).

We also do not incorporate the Arctic Basin subpopulation into our analyses. This subpopulation was defined by the IUCN in 2001 (Lunn et al. 2002) to recognize bears which may reside outside the territorial jurisdictions of the polar nations. The Arctic Basin region is characterized by very deep water which is known to be unproductive (Pomeroy 1997). Available data are conclusive that polar bears prefer sea-ice over shallow water (<300m deep) (Amstrup et al. 2000, 2004a; Durner et al. 2007), and it is thought that this preference reflects increased hunting opportunities over more productive waters. Indeed, polar bears from coastal regions will use the central Arctic Basin seasonally, but tracking studies indicate that few if any bears are year-round residents of the central Arctic Basin.

Although each of the areas where the 19 individual IUCN subpopulations occur have unique characteristics, we pooled them into four ecological regions (Figure 1). We defined "ecoregions" on the basis of observed temporal and spatial patterns of ice formation and ablation (melting or evaporation), observations of how polar bears respond to those patterns, and how general circulation models (GCMs) forecast future ice patterns. We defined these four ecoregions as: 1) Seasonal Ice (or Seasonal) Ecoregion; 2) the Canadian Arctic Archipelago (Archipelago Ecoregion); 3) the Polar Basin Divergent Ecoregion; and 4) the Polar Basin Convergent Ecoregion. Splitting the polar basin into 2 ecoregions was based upon their different patterns of sea ice formation, ablation and advection (transport by the wind or currents) (Rigor et al. 2002; Rigor and Wallace 2004; Maslanik et al. 2007; Meier et al. 2007; Ogi and Wallace 2007). The Polar Basin Divergent Ecoregion is characterized by extensive formation of annual sea ice which is then advected into the center of the polar basin or out of the polar basin through Fram Strait. The Polar Basin Divergent Ecoregion lies between ~127° W longitude and 10° E longitude and includes the southern Beaufort, Chukchi, East Siberian-Laptev, Kara, and Barents seas. The Polar Basin Convergent Ecoregion is the remainder of the polar basin including the east Greenland Sea, the continental shelf areas adjacent to northern Greenland and the Queen Elizabeth Islands, and the northern Beaufort Sea (Figure 1).

Modeling

Overview

We projected the future status of polar bear populations in each of the four ecoregions, which collectively encompass the entire range of polar bear distributions range-wide. Both the carrying capacity and the BN models were applied to each of the four ecoregions at five time periods relative to present (years -10, 0, 45, 75, and 100). Analyses included historic and current habitat conditions from the satellite-observed ice data for years -10 and 0, and future habitat conditions from GCM ice projections for years 45, 75, and 100. Because multiple GCM model runs were not available, we did not have samples from which true process variation could be estimated. To capture the full range of variation, however, we developed estimates from: 1) the multi-model (ensemble) means of the 10 GCMs, 2) the GCM that projected the minimum ice extent, and 3) the GCM that projected the maximum ice extent—for each ecoregion in each time period. See DeWeaver (2007) and Durner et al. (2007) for a thorough discussion of the range in values among GCMs.

Sea-ice habitat variables

Our forecast of future carrying capacity of polar bears was based entirely on historic and current observations, and future GCM projections of future sea ice habitat for polar bears. Our BN model then incorporated changes in sea-ice habitat distribution as one of the "stressors" which might help predict the future of polar bears. Hence both approaches depended upon an assessment of polar bear habitat and projections of how future habitat might be different than now (Figure 2). For modeling, we needed consistent metrics of polar bear habitat that would facilitate temporal comparisons. We defined two such metrics: 1) polar bear habitat as simply the area of sea ice over the continental shelf; and 2) optimal sea ice habitat—defined as ice with characteristics shown to be preferred by polar bears through development and application of resource selections functions (RSFs).

Durner et al. (2007) used polar bear satellite tracking data and monthly ice concentration observations derived from passive microwave satellite imagery (Cavalieri et al. 1999) to develop RSFs that estimated relative probabilities of habitat use in the two pelagic ecoregions of the polar basin. RSFs were built only for the polar basin where radiolocation data had sufficient sample size. Durner et al. (2007) constructed four seasonal RSF models (winter, spring, summer, and autumn) using data collected during 1985–1995. Durner et al. (2007) then extrapolated the RSF models using sea ice projections from each of 10 GCMs (Table 1) that were selected for analysis because their 20th century simulations were better aligned with the observational ice record (DeWeaver 2007).

For each season, Durner et al. (2007) calculated the average 1985–1995 RSF threshold that separated the upper 20% from the lower 80% of the RSF-valued habitat area, and termed the upper 20% "optimal habitat" because those areas were occupied by over 70% of the bear locations. These 1985–1995 thresholds were used to extract the area of optimal habitat in all months of the 21st-century RSF extrapolations from all 10 GCMs. Using the 1985–1995 period to define the thresholds provided Durner et al. a foundation that allowed them to examine whether future ice projections indicated increases, decreases, or stability in the cumulative annual area of optimal polar bear habitat.

We used three types of monthly maps from the Durner et al. (2007) study: 1) Arctic-wide observed sea ice concentrations (1979–2006); 2) Arctic-wide 21st-century sea ice projections by 10 GCMs; and 3) both observed and projected areas of optimal polar bear sea-ice habitat in the two pelagic polar basin ecoregions. From the observed and projected Arctic-wide sea ice concentration maps, we defined and extracted "total available ice habitat" as the annual 12-month sum of sea ice cover over the continental shelves of the two polar basin ecoregions. Ice cover was defined as the aerial extent (km^2) of all pixels with ≥50% ice concentration. Since deep water is uncommon in the archipelago and seasonal ice ecoregions, we considered those entire areas to effectively reside over the continental shelf, meaning total ice habitat equated to total ice cover.

We note that expressing changes in sea-ice habitat over time on the basis of annual km^2-months tends to minimize the potential effects of sea ice habitat changes projected for the future as well as those that have been observed may have on polar bears. Whereas the yearly average sea ice extent has declined at a rate of 3.6% per decade, the mean September sea ice extent has declined at a rate of 8.4% per decade (Meier et al. 2007). Further, all GCMs project extensive winter sea ice through the end of the 21st century in most ecoregions (Durner et al. 2007). Therefore the severity of summer periods of food deprivation may be hidden by extensive sea ice in winter. Although polar bears are well adapted to a feast and famine diet (Watts and Hansen 1987), there apparently are limits to their ability to sustain long periods of food deprivation (Regehr et al. 2007b). We recognize that our measure of change in km^2-months will be largely insensitive to seasonal effects.

We used the baseline period 1985-1995 to define high-value (optimal) habitat because during this early period of our studies, year-round polar bear movements were less restricted than they were in recent years when sea ice extent was more spatially reduced. The 4 seasonal RSF thresholds, derived from the 1985-1995 period, remained fixed for all time steps in our projections. Thus, when we extracted the area of optimal habitat from RSF maps generated from outputs of GCMs, the threshold values for optimal habitat were those observed in 1985-1995. This approach created a foundation that allowed us to examine whether future ice projections indicated increases, decreases, or stability in the cumulative annual area of optimal polar bear habitat relative to our earliest decade of empirical observations. Inherently, this approach assumes that polar bears in the future will select habitats in the same way they did between 1985-1995 despite seasonal changes in ice extent and distribution.

Other key sea ice factors of interest included how climate warming may produce changes in the duration and distance that ice retreats from the continental shelf regions. Using the observed and projected ice concentration maps, we extracted and summed the annual number of ice-free months in each ecoregion. An ice-free month occurred when the proportion of ice cover (defined above) over the continental shelf dropped below 50% (again, the archipelago and seasonal ecoregions were considered entirely shelf waters). In other words, we considered the availability of *total habitat* to be compromised if less than half of the shelf-waters were ice-covered; hence the respective month was classified as ice-free. Also for each year, for the month of minimum ice extent, we calculated the mean distance from every pixel in an ecoregion to the nearest sea ice.

Carrying Capacity Model

We developed deterministic calculations of polar bear carrying capacity for each combination of ecoregion, time step, and future minimum, maximum, and multi-model mean GCM projections. Deterministic projections were calculated in Microsoft Excel®. Calculations in the model components are described below.

Habitat amount

First, we compiled the amount of total ice habitat and optimal habitat from the observed sea ice record and from the GCM projections. Specifically, the total annual (Σ 12 months) habitat amount $H_{t,G}$ was expressed for each of the four ecoregions G and each of the five yearly time periods t as km^2-months. For the two polar basin ecoregions (where the RSF study was conducted) we subtracted the optimal habitat area from the estimates of total ice habitat to provide an area of non-optimal habitat.

Change in habitat amount

Despite overall agreement in the direction of change in sea ice extent, there is considerable variability among the GCMs in their simulations of present-day ice extent, as well as disparity with the observed sea ice record (Figure 3). These disparities reflect aspects of GCM model uncertainties that are introduced by many factors (DeWeaver 2007). Disparities of GCM model predictions with known conditions are not surprising because GCMs are constructed to emulate natural climate variability (Wang et al. 2007). Amounts of ice predicted by the GCM model might not perfectly match amount observed because the observed climate is but one realization of the possible modeled outcomes.

When comparing modeled futures to the present, it would make no sense to project the trends forward from a baseline that "could have been." Rather, the sensible approach is to use the GCM's projected rates of habitat change, and apply those rates of change to the actual observed baseline. To this end, we compared the habitat projections at each time step to each model's "time zero" value, and calculated the percent change in habitat projected by each model relative to itself. This calibrating or normalizing of the estimates of available habitat provided all model results with a common beginning or baseline value in year 0, and took full advantage of the rate of change projected by each model.

We calculated the percent change in habitat amount H at time t with respect to year 0, for each geographic region G, as

$$CH_{t,G} = 100 * \frac{(H_{t,G} - H_{0,G})}{H_{0,G}}.$$

One outcome of the calculation of $CH_{t,G}$ was that estimates at year 0 varied among GCM runs. Another outcome of these calculations is that compared to the observed ice extent, the GCM ensemble mean, and most individual models, overestimated ice extent in the study area in both the late-20th century simulations and the early-21[st] century projections. Furthermore, the recent rate of summer ice decline in the observed data shows a trajectory that is steeper than that of the GCM ensemble mean during the early 21[st] century. This is a reflection of Stroeve et al.'s (2007) conclusion that Arctic sea ice may be disappearing at a rate that is "faster than forecasted".

Our normalized $CH_{t,G}$ was further interpreted into categories of direction of change, magnitude of change, and a composite summary of magnitude and direction. Direction was categorized into "contracting" if $CH_{t,G} < 0$ or "expanding or stable" if $CH_{t,G} \geq 0$. Magnitude was categorized into "fast" if $|CH_{t,G}| > 30.0$, "moderate" if $15.0 < |CH_{t,G}| \leq 30.0$, and "slow or none" if $|CH_{t,G}|$ 15.0. We also make available the specific results for $CH_{t,G}$ so that alternative cutoff values for such categories could be examined if desired. The summary category for habitat change was then based on the habitat change direction category and the magnitude category, as shown in Table 4.

Polar bear densities

We used the most recent estimated population size for each IUCN subpopulation (Aars et al. 2006, Table 5) to calculate polar bear densities. Because estimates were not provided for the East Greenland and Kara Sea subpopulations, we surmised numbers that seemed appropriate based upon the area of habitat and records of harvest where available. Accuracy of the year 0 density estimates is not critical because our goal was to express the relative changes that are likely to occur. In other words, although the numbers of bears in many of the world's subpopulations are poorly known, our projections of trends in those numbers in this model are valid to the extent that sea ice quantity alone determines polar bear carrying capacity.

We calculated polar bear densities based on observed total ice habitat in each of the four ecoregions. We also calculated polar bear densities based on optimal habitat in each of the two polar basin ecoregions. Following examples in the ecological literature, we refer to the densities estimated from total and optimal habitat as "crude" and "ecological," respectively (Rinkevich and Gutiérrez 1996; Diller and Thome 1999). We calculated densities as follows. First we tallied present-day (year 0) polar bear population sizes $N_{0,G}$ in each of the four ecoregions G. We then calculated polar bear densities as

$$D_G = \frac{H_{0,G}}{N_{0,G}},$$

expressed as habitat area (km^2-months x 1000) per bear, using the estimates of habitat at year 0 from satellite data. We expressed density in terms of habitat area per bear to avoid the excessively small values that would result from expressing density in terms of bears per area.

We calculated total densities based on total ice habitat area for the Seasonal and Archipelago ecoregions, and we calculated "ecological" and "crude" densities based on optimal habitat and and non-optimal habitat area, respectively, for the Polar Basin Divergent and Convergent ecoregions. Empirical observations indicated that polar bears spend 70% of their time in the portion of the habitat that we called optimal (Durner et al. 2007). We extrapolated this to mean that at any snapshot in time, 70% of the bears in the two polar basin ecoregions were within the identified optimal habitat. We used 70% to estimate an ecological density in the optimal habitat. The remaining 30% of bears in each ecoregion were assigned to the non-optimal habitat to calculate a crude density. All polar bear density calculations were based on year 0 numbers of bears and habitat area, and then applied to other past and future time periods. This assumed that densities are invariant over time in terms of describing potential carrying capacity levels.

Polar bear carrying capacity

We applied year 0 polar bear densities to habitat area in each time period to calculate polar bear carrying capacity $K_{t,G}$ for each combination of time period t, ecoregion G, and minimum, maximum, and ensemble mean GCM habitat values. The calculation was:

$$K_{t,G} = H_t \,/\, D_G .$$

We used the normalized percent change in habitat to derive values for available habitat at each time step. This assured that our estimates of changes in carrying capacity coincided with the projected estimate of available habitat at each time step. Specifically, we calculated percent change $CK_{t,G}$ in $K_{t,G}$ from year 0 values, as

$$CK_{t,G} = 100 * \frac{(K_{t,G} - K_{0,G})}{K_{0,G}}.$$

This was done for all habitats in the Seasonal Ice and Archipelago ecoregions, and separately for optimal habitat and non-optimal habitat in the Divergent and Convergent ecoregions. We then applied each of the percent change values $CK_{t,G}$ to the estimate of carrying capacity at year 0 $K_{0,G}$ (based on the observed data), to recalculate a normalized value of carrying capacity as

$$K_{t,G}^{norm} = K_{0,G} * \left(1 + \frac{CK_{t,G}}{100}\right).$$

In this way, the values of normalized carrying capacity $K_{t,G}^{norm}$ can be compared over time periods (historic, current, and future) for each of the GCM model run scenarios (minimum, ensemble mean, and maximum) in parity.

Percent change in carrying capacity

We divided the values of change in carrying capacity $CK_{t,G}$ into categories of direction, magnitude, and composite outcomes. Direction was categorized into "decreasing" if $CK_{t,G} < 0$ or "stable or increasing" if $CK_{t,G} \geq 0$. Magnitude was categorized into "high" if $|CK_{t,G}| > 30.0$, "moderate" if $15.0 < |CK_{t,G}| \leq 30.0$, and "low to none" if $|CK_{t,G}| < 15.0$. We make available the specific results for $CK_{t,G}$ so alternative cutoff values can be examined if desired. The summary categories of carrying capacity change were then derived from the direction and magnitude categories, as shown in Table 6.

Assigning Status Categories Based on Carrying Capacity Change

We categorized outcomes of habitat change and carrying capacity change into 4 composite summary categories to describe the status of polar bear populations: enhanced, maintained, decreased, and toward extirpation (Table 2). The composite summary categories express very general classes of carrying capacity levels as compared with current levels, and basically constitute a simple rule set for expressing outcomes in ordinal scale classes. We provide categorical outcomes to depict future polar bear carrying capacity levels in a simple, understandable manner that is relatively insensitive to the accuracy of specific calculations or assumptions. We started these computations with the best estimates available of sea ice habitats and polar bear numbers, and we applied those estimates to the best available GCM projections.

As mentioned previously, many polar bear population estimates were crude, and the assumption that polar bear density would not change over time is almost certainly not valid. Collapsing the numerical outcomes of this process into intuitive categories of qualitative results, however, converts the actual numbers to only four general classes. The carrying capacity model is not a demographic model, nor is it an estimation of actual, expected population sizes of polar bears. It is a calculation only of possible carrying capacity and changes thereof, assuming no effects from anthropogenic stressors or environmental factors other than the losses of habitat forecasted by GCMs.

Bayesian Network Population Stressor Model

Our second method of forecasting the status of polar bears in the 21st century involved the development of a prototype Bayesian network (BN) model that accommodates the potential effects of multiple stressors on polar bear populations. Inputs to our BN model included various categories of natural and anthropogenic stressors (Barrett 1981; Anderson et al. 2000), and key environmental factors that affect polar bear populations. Anthropogenic stressors included various human activities that could affect the distribution or abundance of polar bears, such as harvest, pollution, oil and gas development, shipping, direct bear-human interactions, and others. Natural stressors on polar bears included changes in the availability of primary and alternate prey and foraging areas, and occurrence of parasites, disease, and predation (Ramsay and Stirling 1984; Amstrup et al. 2006). Other key environmental factors included projected changes in total ice and optimal habitat, changes in the distance that ice retreats from traditional autumn or winter foraging areas, and changes in the number of months per year that ice is absent in the continental shelf regions. Collectively, the anthropogenic stressors, natural disturbances, and other key environmental factors were structured in a BN model in terms of how they affect polar bear demography and use of foraging areas, and ultimately, how they affect polar bear distribution and abundance.

Below, we provide a general description of BN models and their use in ecological applications. We then describe how we developed the population stressor model for polar bears, how results from the model were analyzed, how we analyzed the model results, and how we conducted sensitivity analyses.

What are Bayesian network models?

A Bayesian network is a graphical model that represents a set of variables that are linked by probabilities1 (Neopolitan 2003; McCann et al. 2006). BNs are comprised of variable nodes and their links. Nodes can represent correlates or causal variables that affect some outcome of interest, and the links define which specific variables directly affect which other specific variables. A BN defines a causal web with probabilistic links, whereby specifying the conditions of some variables can predict the outcome of some other variables. In this way, BNs constitute what are called influence diagrams (Marcot et al. 2006). BNs provide an efficient way to represent and summarize understanding of a system, and can combine expert knowledge and empirical data into the same modeling structure. Crafting a BN allows one to better understand the relationships and sensitivities among the elements of the causal web, and to provide insights into the workings of the system that otherwise would not have been evident.

Each node in a BN model typically is depicted with two or more mutually exclusive states. BN nodes can represent categorical, ordinal, or continuous variable states or constant (scalar) values. Each node typically has an associated probability table that describes either its prior (unconditional) probabilities of each state for input nodes, or its conditional probabilities of each state for nodes that directly depend on other nodes (see Marcot et al. 2006) for a description of the underlying statistics). BNs are "solved" by specifying the values of input nodes and having the model calculate posterior probabilities of the outcome node(s) through standard "Bayesian learning," which is the application of Bayes' theorem (Jensen 2001; see also footnote 1).

Use of Bayesian networks in ecological modeling

BNs are being increasingly used in ecological and natural resource modeling. Examples include use of BNs to model population viability of salmonid fishes (Lee and Rieman 1997), habitat restoration potential for rare wildlife species (Marcot et al. 2001;

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[1] In BNs, input nodes contain unconditional prior probabilities of their states. The states are assumed to be mutually exclusive and the probabilities sum to one. Prior probabilities are distributed as discontinuous Dirichlet functions in the form of $D(x)=\lim_{m\to\infty}\lim_{n\to\infty}\cos^{2n}(m!\pi x)$, which is a multivariate, n-state generalization of the two-state Beta distribution with state probabilities being continuous within [0,1]. States S of output nodes contain posterior probabilities that are calculated conditional upon nodes H that directly affect them, using Bayes Theorem, as $P(S\mid H)=\frac{P(H\mid S)P(S)}{P(H)}$ (see Jensen 2001 and Marcot 2006 for further explanation of the statistical basis of BNs).

Wisdom et al. 2002), effects of habitat alteration on populations of native ungulates (McNay et al. 2006), and many other applications (Marcot 2007). BNs are useful for modeling systems where empirical data are lacking, but variable interactions and their uncertainties can be depicted based on expert judgment (Das 2000). They are also particularly useful in efforts to synthesize large amounts of divergent quantitative and qualitative information to answer "what if" kinds of questions. Their ability to examine "what if" questions has led to insights regarding the prognosis for how global warming may impact coral reefs, and the degree to which local management actions may be able to offset some effects of rising temperatures (Wooldridge and Done 2004; Wooldridge et al. 2005).

Structuring the Bayesian network population stressor model for polar bears

Developing a BN model entails depicting the "causal web" of interacting variables (nodes) in an influence diagram (that is, describing the general structure of the model), assigning states to each node, and assigning probabilities to each node that define the conditions under which each state would result. BNs can be built from a combination of empirical data and expert judgment, and can be built using commercially-available modeling shells. We used the modeling shell Netica® (Norsys, Inc.), and followed guidelines for developing BN models developed by Jensen (2001), Cain (2001) and Marcot et al. (2006).

The BN model we developed for polar bears depicted the potential population influences from multiple stressors and environmental conditions that were not captured in the simple carrying capacity model described earlier. Our BN stressor model was based on the knowledge of one polar bear expert (S. Amstrup) who established the model structure and probability tables according to expected influences among variables. B. Marcot served as a "knowledge engineer" or model engineer, and provided guidance to help structure the expert's knowledge into an appropriate BN format. An initial list of ecological correlates was compiled by the expert, which were then organized into an influence diagram (Figure 4). Through discussion and questioning, the model engineer guided the expert through several stages to a final structure. The interactive sessions were useful in exploring alternative means of depicting influences among variables, ways to summarize influences into categories of numerical and distribution responses which could be useful to managers, and ways of representing some variables with proxies.

The BN model structure was divided into three kinds of nodes: (1) input nodes that were the anthropogenic stressor or environmental variables and used unconditional probabilities to parameterize their states; (2) summary nodes that collected and summarized effects of multiple input nodes and used conditional probabilities to calculate their states; and (3) output nodes that represented numerical, distribution, and overall population responses to the suite of stressors and environmental conditions. The output nodes used Bayesian learning to calculate posterior probabilities of their final outcome states. Summary nodes in the model served to "gather" and depict the joint influence of several inputs, and constituted what are sometimes called latent variables in the ecological modeling literature (e.g., Bollen 1989). Including latent variable nodes in the BN model was also helpful in establishing probability tables in each node and for characterizing general categories of the input (stressor) nodes. We went through many iterations of the model structure to ensure that it responded to particular input conditions in ways that paralleled responses of polar bear populations which have been observed, or for which there are strong prevailing hypotheses in the biological community.

The overall outcome of our BN model was a statement of the relative probabilities that the population in each ecoregion would be larger than now, same as now, smaller, rare, or extinct. The overall outcome was determined by nodes which summarized the likely numerical and distribution response of polar bears to projected changes in their environment. Responses of polar bears to projected habitat changes and other potential stressors could affect polar bear distribution or polar bear numbers independently in some cases, or they could affect both distribution and numbers simultaneously. Our approach allowed for independent or linked numerical and distributional responses. The factors influencing numerical and distribution responses were, in turn, further defined in terms of more specific human stressor, natural disturbance, or key environmental correlate variables (Figure 5).

Because our purpose was to inform the decision of whether to list polar bears as a threatened species, we designed the summary nodes in the BN model to include four of the five major listing factors used to determine a species' status according to the Endangered Species Act (U.S. Fish and Wildlife Service 2007). We included summary nodes for Factor A—habitat threats; Factor B—overutilization; Factor C—disease and predation; and Factor E—other natural or man-made factors. We did not include Factor D—inadequacy of existing regulatory mechanisms, because our model focused on ecosystem effects; however, regulatory aspects could be seamlessly added at a future time. Inclusion of these summary nodes recognized the listing factors as important potential stressors and also acknowledged the work done by the FWS during development of the proposal to list polar bears. Structuring the BN model in this way, therefore, helps assure its relevance to the listing process. This structure also anticipates that our BN stressor model could provide a foundation for a decision model specific to Endangered Species Act listing criteria for this species.

Parameterizing the Bayesian network model

Model input nodes were parameterized with data on ice extent, length of time that ice was projected to be away from identified foraging areas, and the distance of ice retreat from such areas (Table 3). Other nodes incorporated qualitative descriptions of possible states of important environmental correlates. Because we were interested in forecasting changes from current conditions, states of each node were expressed categorically as "compared to now." That is, they could be in a condition similar to present, they could be in better condition than present, or they could be in worse condition. We set prior probabilities of all input nodes to uniform distributions (complete uncertainty), but before the model was run, we specified the states that seemed most probable (Table 3).

States of environmental correlates were established under each combination of time step, ecoregion, and GCM model outputs. We parameterized the conditional probability tables to assure that node structures were specified in accordance with available polar bear data or expert understanding of data. After initially populating and inspecting the conditional probability tables, we used three different methods to arrive at final values: 1) sensitivity analyses of subparts of the model, 2) solving the model backwards by specifying outcome states and evaluating if the most likely input states tbat were returned were plausible according to what we know about polar bears now, and 3) running the model (and subparts) forward to ascertain if the summary and outcome nodes responded as expected given the states of the input nodes. These approaches constituted initial calibration of the model to the expert's knowledge about polar bears and bow polar bears are likely to respond to various circumstances. In sum, the goals of this first-generation BN model were to ensure that input conditions matched the current understanding of polar bear biology ecology and responses to observed changes, and that it responded to particular input conditions in ways that paralleled observed responses of polar bear populations.

As fully specified, the BN model included probability tables for each node (Figure 5, Appendix 2, 3). The BN model ultimately consisted of 38 nodes, 44 links, and 1,667 conditional probability values specified by the modelers. The model was solved for each combination of 4 ecoregions, 5 time periods, and 3 future GCM scenarios (ensemble mean, maximum, and minimum). Specifically, for each ecoregion and time period, the three future GCM scenarios were: 1) results projected by the ensemble mean of all 10 GCMs ; 2) results projected by the GCM that forecasted the greatest retention of sea ice; and 3) results projected by the GCM that forecasted the lowest retention of sea ice. Only one data source (the observed record of sea ice) was examined for the historic (1985-1995) and current (1996-2006) time periods. In total, we examined 44 unique combinations. We evaluated correlations among input nodes and between input and output nodes, to assure that colinearity among inputs was not unduly affecting outcome states.

The input data to run each combination were specified by summarizing the respective GCM-derived habitat variables, and by best professional judgment of polar bear expert S. Amstrup (Table 3). Because BN models combine expert judgment and interpretation with quantitative and qualitative empirical information, inputs from multiple experts are usually incorporated into the structure and parameterization of a "final" model. Due to time constraints, however, we were not able to seek and incorporate the input of multiple polar bear experts. Therefore, the model presented here should be viewed as a first-generation prototype. The model will be refined through formally developed processes (see Discussion) at a future time.

Bayesian network model output states

Principal results of the BN model are levels of relative probabilities for the potential states at outcome nodes. In the polar bear BN population stressor model, outcomes of greatest interest were 1) those related to listing factors used by the FWS, 2) the distribution responses, 3) numerical responses, and 4) the overall population response. We evaluated the BN outcomes in terms of the most probable outcome at each of the time steps, and the dispersion of probabilities among all outcomes. Probabilities are presented for each ecoregion and for each of the GCM scenarios we examined. We assessed results from the BN model in the statistical software package SYSTAT 11 (SYSTAT 2004).

We defined our principal outcome nodes (shown in Figure 5) and their possible states as follows:

Node C4: Numerical Response

This node represents the anticipated numerical response of polar bears in an ecoregion based upon the sum total of the identified factors which are likely to have affected numbers of polar bears in any particular area. Such factors include net reproduction as affected by ice habitat conditions, and influences of disease, predation, intentional takes, and human disturbances and stressors. Numerical response outcome states were defined as follows:

- <u>increased density</u> = polar bear density greater than that at Year 0 (year 2000); the density level could be determined empirically to be significantly greater than that at Year 0; density can be expressed in terms of number of polar bears per unit area of optimal habitat (thus expressing "ecological density") or of total (optimal plus suboptimal) habitat (thus expressing "crude density");

- same as now = polar bear density as above but equivalent to the density at Year 0; the density level could be determined empirically to not be different from that at Year 0;
- reduced density = polar bear density less than that at Year 0 (year 2000) but greater than one-half of the density at Year 0; the density level could be determined empirically to be significantly less than that at Year 0 and also significantly greater than one-half of the density at Year 0;
- rare = polar bear density less than half of that at Year 0 (year 2000); the density level could be determined empirically to be significantly less than that one-half that at Year 0;
- absent = polar bears are not demonstrably present; polar bear density is not significantly different than zero.

Node C3: Distribution Response

This is the sum total of ecological and human factors that predict the future distribution of polar bears in the ecoregion. Distribution refers here to the *functional response* of polar bears (viz., movement and spatial redistribution of bears) to conditions of ice habitat quantity, quality, and temporal distribution; availability of prey and foraging areas; and human disturbances and stressors. Distribution response outcome states were defined as follows:

- same as now = polar bear distribution equivalent to that at Year 0; distribution could be determined empirically to not be different from that at Year 0;
- reduced but resident = a condition in which habitat or prey availability have changed in a way that would likely lead to a significantly reduced spatial distribution (e.g. due to avoidance of a human development, or sea ice is still present in the area but in more limited quantity). Bears would still occur in the area, but their spatial distribution would be more limited than at Year 0;
- transient visitors = a condition in which habitat or prey availability are seasonally limited or human activities have resulted in a situation where available ice is precluded from use by polar bears on a seasonal basis;
- extirpated = a condition in which habitat or prey availability have declined and human stressors have increased in such a way as to render the area essentially unusable by polar bears, and have lead to a complete or effective dearth of polar bears in the area.

Node D1: Overall Population Outcome

Overall population outcome refers to the collective influence of both numerical response and distribution response. It incorporates the full suite of effects from all anthropogenic stressors, natural disturbances, and environmental conditions on the expected occurrence and levels of polar bear populations in the ecoregion. Overall population outcome states were defined as follows:

- larger = polar bear populations have a numerical response greater than at present (Year 0) and a distribution response at least the same as at present (that is, able to use available habitat, to relocate if possible and needed, and to withstand anthropogenic stressors);
- same as now = polar bear populations have a numerical response essentially the same as at present (Year 0) and a distribution response at least the same as at present;
- smaller = polar bear populations have a reduced density and a distribution response the same as at present or reduced but resident; or have a density same as at present but occur as reduced but resident or transient visitors;

- rare = polar bears are numerically rare and have a distribution response same as at present, or occur as reduced but resident or transient visitors; or have a reduced density and occur as transient visitors;
- extinct = polar bears are numerically absent or distributionally extirpated.

Here, the "extinct" state refers to conditions of: (1) complete absence of the species (N=0) from an ecoregion; or (2) numbers and distributions below a "quasi-extinction" level, that refers to a non-zero population level at or below which the population is near extinction (Ginzburg et al. 1982; Otway et al. 2004); or (3) functional extinction, that refers to being so scarce as to be near extinction and contributing negligibly to ecosystem processes (Sekercioglu et al. 2004; McConkey and Drake 2006).

Our final BN model was structured to make maximum use of the data and GCM outcomes describing observed and projected changes in the sea ice. Knowledge of polar bears, their dependence on sea ice, and the ways in which sea ice changes have been observed to affect polar bears, were used to populate the conditional probability tables. The BN model also incorporated professional judgment regarding how other ecological and human factors may change if sea ice changes occur as projected. Because our prototype model was parameterized by the best professional judgment of only one polar bear expert, it is reasonable to ask how robust the results might be to input probabilities which could vary among other experts. It also is appropriate to ask whether it is likely that future sea ice change, to which model outcomes are very sensitive, could fall into ranges that would result in qualitatively different outcomes than our BN model projects. Finally, it is appropriate to ask the extent to which model outcomes may be altered by active management of the states of nodes which represent variables which are under human control.

We addressed questions about the ability of changes in human activities to alter the BN output states by fixing inputs which humans could control and examining differences in the overall outcomes. We evaluated the extent to which sea ice projections would have to differ to make qualitative differences in outcomes by holding all non-ice variables at uniform priors and allowing ice variables only to vary at future time steps. Comparing those results to the range of ice conditions available from GCMs provides a sense of just how much the realized future ice conditions would have to change from those projected to make a difference in population outcomes. Finally, although we cannot second guess how other polar bear experts may recommend parameterizing and structuring the model, comparison of model runs with preset values provides some sense of how much differently the model would have to be parameterized to project patterns qualitatively different than those we observed.

After the BN population stressor model was finalized, we ran overall sensitivity analyses to determine the degree to which each input and summary variable influenced the population outcome variables. We used results of sensitivity analysis to determine the potential effect of each stressor variable on the anticipated polar bear numerical response, distribution response, and overall population outcome.

For discrete and categorical variables, sensitivity was calculated in the modeling shell Netica as the degree of entropy reduction (reduction in the disorder or variation) at one node relative to the information represented in other nodes of the model. That is, the sensitivity tests indicate how much of the variation in the node in question, is explained by each of the other nodes considered. That is, "node X explains this much of the variation in node Y." [See chapter 2 in Burnham and Anderson (1998) for a summary discussion of the entropy concept.] The degree of entropy reduction, I, is the expected reduction in mutual information of an output variable Q with q states due to a finding of an input variable F with f states. For discrete variables, I is measured in terms of information bits and is calculated as:

$$I = H(Q) - H(Q \mid F) = \sum_q \sum_f \frac{P(q,f)\log_2[P(q,f)]}{P(q)P(f)}$$

where $H(Q)$ is the entropy of Q before new findings are applied to input node F, and $H(Q|F)$ is the entropy of Q after new findings are applied to F. In Netica, entropy reduction is also termed mutual information.

For continuous variables, sensitivity is calculated as variance reduction VR, which is the expected reduction in variation, $V(Q)$, of the expected real value of the output variable Q due to the value of input variable F, and is calculated as

$$VR = V(Q) - V(Q \mid F),$$

where

$$V(Q) = \sum_q P(q)[X_q - E(Q)]^2,$$

$$V(Q \mid F) = \sum_q P(q \mid f)[X_q - E(Q \mid f)]^2,$$

and

$$E(Q) = \sum_q P(q)X_q,$$

and where X_q is the numeric real value corresponding to state q, $E(Q)$ is the expected real value of Q before new findings are applied, $E(Q|F)$ is the expected real value of Q after new findings f are applied to F, and $V(Q)$ is the variance in the real value of Q before any new findings (Marcot et al. 2006)

The greater the values of I or VR, the greater is the influence of input variable F on output variable Q. In this way, we were able to assign an order to the potential influence of each input and summary node on the population outcome nodes, and thereby describe the overall sensitivity structure of the model.

Results

In this section we first present the projection of carrying capacities for polar bears in each ecoregion based on a presumed linear relationship between sea ice extent and polar bear numbers. That projection, which does not include seasonal changes in the sea ice, or other factors which could be population stressors, provides an upper bound on polar bear populations that could be supported by sea ice habitat available in the future. We next present projections based on the BN population stressor model. Because it incorporated many of the factors not included in the projection of carrying capacity, it provides a more thorough assessment of the future of polar bears in each ecoregion.

Forecasted 21st Century Polar Bear Carrying Capacity

Habitat area and change

Total habitat area, expressed as the annual sum of km^2-months of sea ice extent, was projected by the GCM models to be reduced (Figure 3) from present-day conditions, at each time step in each ecoregion and for all ecoregions combined (global). Proportional declines in available total babitat ranged from relatively modest (less than 15% decline from present) at year 45 in the Seasonal Ice Ecoregion, to large (more than 47% decline) by year 100 in the Polar Basin Divergent Ecoregion (Table 4, Figures 6, 7). For all combinations of time steps, GCM runs, and ecoregions, both total and optimal habitat were projected to be less abundant than present amounts (Table 4, Figures 6, 7). Globally, projected habitat declines were 24%, 18%, and 15% for the minimum, mean, and maximum GCM model inputs, respectively, by year 45. Equivalent global values at year 100 were 40%, 32%, and 23% for minimum, mean, and maximum ice projections, respectively. Using the satellite observed sea ice record, total habitat area during the previous decade (year -10) varied among ecoregions and was between 3% and 17% more abundant than at present. Globally, total habitat in the last decade was 7% more abundant than it is now (Figures 6, 7).

Polar bear carrying capacity

Current estimated polar bear densities ranged from a high of $0.923*10^3$ km^2-months per bear in the Polar Basin Convergent Ecoregion, to a low of $7.695*10^3$ km^2-months per bear in the non-optimal portion of the Polar Basin Divergent Ecoregion (Table 5). Estimates of polar bear carrying capacity ($K_{t,G}$) based upon these densities, as well as percent change in carrying capacity from present ($CK_{t,G}$), and carrying capacity normalized to present ($K_{t,G}^{norm}$), are presented in Table 6, and Figures 8 and 9. As with total habitat, total historical carrying capacity (year -10) ranged from 3 to 17% greater than at present in the Archipelago and Seasonal Ice Ecoregions, respectively, and 8% globally (Figure 9).

In the Seasonal Ice Ecoregion, we projected total carrying capacity to decline 7-10% from present levels by year 45, 21-32% by year 75, and 22-32% by year 100 (ranges of percentages depending on habitat amount predicted by the GCM maximum and GCM minimum results, respectively; Table 6, Figures 8, 9). In the Archipelago Ecoregion, we projected total carrying capacity to decline 3-14% from present levels by year 45, 18-21% by year 75, and 21-24% by year 100. In the Polar Basin Divergent Ecoregion, total carrying capacity dropped 19-35% from present levels by year 45, 29-43% by year 75, and 23-48% by year 100. In the Polar Basin Convergent Ecoregion, total carrying capacity ranged from -24% to +4% of present levels by year 45, and dropped 8-28% by year 75, and 3-31% by year 100.

For the two polar basin ecoregions, model data also were available on amount of optimal habitat and carrying capacity within optimal habitat (Tables 2,4; Figs. 7,8). In the Polar Basin Divergent Ecoregion, we projected carrying capacity of optimal habitat to drop 17-36% at year 45, 31-45% at year 75, and 21-49% at year 100, again because of relatively greater loss of optimal habitat. Conversely, the Polar Basin Convergent Ecoregion appeared to largely maintain non-optimal habitat, although there was considerable variation among models and time periods. The increasing proportion of non-optimal habitat along with corresponding increase in its carrying capacity (by as much as 49% by year 45 under the GCM maximum scenario), however, was insufficient to prevent overall declines in total carrying capacity, in most model runs. This was caused by strong declines in the carrying capacity of optimal habitat in latter years of the projections. Nonetheless, projected habitat losses in the Polar Basin Convergent Ecoregion were more modest and more variable among all model runs than in the Polar Basin Divergent Ecoregion. The optimal habitat-based carrying capacity showed declines ranging up to 31% loss by year 100, with no gains in any time period. In all ecoregions, trends consistently suggested moderate to large decreases in total carrying capacity by year 75, and moderate decreases in all ecoregions beginning in year 45. Globally, total carrying capacity across all ecoregions was projected to drop 10-22% from present levels by year 45, 22-32% from present levels by year 75, and 20-37% from present levels by year 100 (Figure 9).

Overall, total carrying capacity was projected to decrease at all time steps we examined in the 21st century. Models which projected minimal ice extent projected trends toward extirpation of bears from the Polar Basin Divergent Ecoregion by year 45 and from the Seasonal Ecoregion by year 75. Under ensemble mean ice conditions, we projected likely extirpation of bears in the Polar Basin Divergent Ecoregion by year 75 and in the Polar Basin Convergent Ecoregion by year 100 (Table 7).

Bayesian Network Model Forecast of the 21st Century Status of Polar Bears

Overall outcomes projected by our BN model which included the consideration of population stressors in addition to sea ice area effects were ranked according to relative probability in Table 8. In all but the Archipelago Ecoregion, the dominant outcome state was "extinct" at all future time periods (Figure 10). Probabilities of the "extinct" state for future time periods varied from a low of 8% in the Archipelago Ecoregion at year 45 under the GCM maximum scenario, to a high of 87% in the Polar Basin Divergent Ecoregion at year 45 under the GCM minimum ice scenario (Table 8, Figure 11).

In the Archipelago Ecoregion, a smaller population was the dominant outcome at year 45 under all GCM scenarios, and at year 75 only for the GCM maximum scenario. Even in the Archipelago Ecoregion, "extinct" was sometimes the dominant outcome for other combinations of time periods and GCM modeling scenarios (Figure 10).

In the Seasonal and Polar Basin Divergent ecoregions, "extinct" was by far the most dominant outcome with very low probabilities forecast for all other outcome states in all time periods. The low probability afforded to outcome states other than extinct suggested a clear trend in these ecoregions toward probable extirpation by mid century. At year 45 in the Polar Basin Convergent Ecoregion, and at all future time steps in the Archipelago Ecoregion, considerable probability fell into outcome states other than extinct (Figure 10). Even when extinct was the most probable outcome, other outcomes sometimes had large non-zero probabilities.

The general trends of the overall population outcome (node D1) from the BN model (Table 8, Figure 10 and 11) can be viewed as follows. In each ecoregion, the polar bear population was very likely larger or at least incurred a far lower likelihood of multiple stressors in the past than compared to present. In the future, however, multiple stressors will likely play important and deleterious roles on all polar bear populations, even starting at year 45, and generally increase in their effect through year 100. Effects of multiple stressors appear to have a composite influence on the overall populations at more or less the same intensities regardless of the GCM modeling scenario (Table 8).

When the overall population outcome is broken down into its component influences, some further differences among ecoregions, time steps, and GCM modeling scenarios become apparent. For instance, there seems to be a greater adverse influence from future conditions on polar bear distribution response (node C3) than on polar bear numerical response (node C4) (Table 9). In part this is because of salient adverse future outcomes of habitat threats (node F2; Table 10) and foraging habitat distribution, especially in the Seasonal and Polar Basin Divergent ecoregions (Table 11). The BN model also represents worsening future conditions of natural disturbances including disease and predation (Table 12) and overall adverse influences on reproduction and vital rates (Table 13).

Sensitivity Structure of the Bayesian Network Population Stressor Model

We conducted 10 tests on the BN population stressor model to determine its sensitivity structure (Appendix 1). In general, the BN model seemed well balanced in terms of its underlying probability tables, in that sensitivity of the final outcome variable (node D1, overall population outcome) was distributed among all arms of the model. In other words, no single input variable or small clique of input variables unduly dominated the overall population outcome (see Appendix 1, sensitivity test 1).

Some 91% of the variation in overall population outcome (node D1) was explained by the top six variables (Appendix 1, Figure 12). Four of those top six variables were sea ice related, including our quantitative data on spatiotemporal change. The ecoregion of consideration and the level of intentional takes rounded-out the top six variables with influence on overall population outcome. In essence, ecoregion also is a habitat variable because ecoregions were specified on the basis of their differences in sea ice. In that context, 5 of the top six variables explaining variation in overall outcome related to the nature of the sea ice.

The primary importance of sea ice change and lesser but complementary importance of anthropogenic stressors carried through to determinations of which FWS listing factors explained the most variation in overall outcome. Relative to the FWS listing factors, overall population outcome was by far most influenced by stressors related to Factor A (habitat threats). Influences from Factor B (overutilization), Factor E (other natural or man-made factors), and Factor C (disease and predation) provided progressively less influence (Appendix 1, sensitivity test 2).

Subsections of the BN model ("submodels") also were tested for sensitivity (Appendix 1, sensitivity tests 5-10). Notable among these tests was that foraging habitat value (node A, a composite "latent variable" created to summarize effects of several key environmental factors), was most sensitive to foraging habitat character, which is a subjective assessment of the quality of sea ice used for foraging by polar bears (Appendix 1, sensitivity test 8). Foraging habitat character (node S1) was included in the BN model to reflect observations that recent changes in the sea ice have included increased roughness and rafting among ice floes that are thought to reduce foraging effectiveness of polar bears (Stirling et al. 2008).

Discussion

We begin this section with a discussion of uncertainty as it pertains to our objectives and our outcomes. We follow a treatment of general uncertainty with a discussion of our carrying capacity model outcomes. Then, we describe the state of development in our BN polar bear population stressor model. That description includes identification of caveats regarding the current stage of development of the model and next steps necessary to address those caveats. Finally, we assess the BN model outcomes with regard to existing knowledge about polar bears and with respect to observed and projected changes in their sea ice habitats on which they depend.

Types and Implications of Uncertainty

Analyses in this report contain three main categories of uncertainty: (1) uncertainty in our understandings of the biological, ecological, and climatological systems; (2) uncertainty in the representation of those understandings in models and statistical descriptions; and (3) uncertainty in model predictions.

First, uncertainty in our understanding of complex ecosystems is virtually inevitable, particularly for one as extensive and remote as the circumpolar Arctic. We have however, incorporated a broad sweep of knowledge regarding polar bears and their environment which is available from published literature, from other reports informing the listing process, and from expert interpretations of that available information.

How to best represent our understanding of the system in models can be structured in various ways. In this report, we captured and represented expert understanding of polar bear habitats and populations in a manner that can be reviewed, tested, verified, calibrated, and amended as appropriate. We have attempted to open the "black box" so to speak, and fully expose all formulas and probabilities used in the polar bear carrying capacity and the BN population stressor models. We also used sensitivity testing to help convey the reliability of BN model depictions (Johnson and Gillingham 2004) (Appendix 1). After BN models of this type are modified through peer review, or revised with knowledge from more than one expert, any variation in resulting models can represent the divergence (or convergence) of expertise and judgment among multiple specialists.

Also included in the second category of uncertainty are uncertainties associated with statistical estimation of parameters such as the extent of sea ice or size of polar bear populations. Statistical estimation typically includes systematic measurement error and random error, for example, as partitioned in general linear models and as may arise in classification functions such as assigning categories to map areas. In this case, we have minimal opportunity to address these estimation errors. The sea ice parameters we used in our polar bear models were derived from GCM outputs, which possess their own wide margins of uncertainty (DeWeaver 2007). Hence, the magnitude and distribution of errors associated with our sea ice parameters were unknown.

To compensate for these unknowns, we accommodated a broad range of sea ice uncertainties by analyzing the 10-member ensemble GCM mean, as well as the minimum and maximum GCM ice forecasts. In the case of polar bear population estimates, many are known so poorly that the best we have are educated guesses. Pooling subpopulations where numbers are merely guesses, with those where precise estimates are available, to gain a range-wide perspective prevents meaningful specific calculation and incorporation of error terms. We recognize that difficulty, but because our projections are expressed in the context of a comparison to present conditions, we largely avoid the issue. That is, whatever the population size is now, the future size is expressed relative to that and all errors are carried forward.

The third category of uncertainty pertains to model predictions. Predictions from models of species abundance and distribution can be subject to at least three sources of error: error due to spatial autocorrelation, dispersal and movement of organisms, and biotic and environmental interactions (Guisan et al. 2006). We addressed these error sources in the following ways. The estimates of ice habitat area were derived separately for each ecoregion from the GCM models because the ecoregions behave independently in terms of sea ice advection. The BN population stressor model accounted explicitly for potential movement of polar bears (e.g., use of alternative foraging areas) and for biotic and environmental interactions (as expressed in the conditional probability tables; see Appendix 3).

Deterministic models, such as the spreadsheet carrying capacity model, present calculations and predictions essentially as point values with no variance or error. In the absence of empirical measures of variation, one could presume a Gaussian error distribution around such calculated predictions. However, in our polar bear carrying capacity model there was no means of determining the magnitude of that error (nor did we have empirical estimates of variation surrounding polar bear population sizes by ecoregion). Hence, we did not attempt to estimate error levels for the carrying capacity calculations, although we acknowledge there is uncertainty surrounding those values.

Probabilistic or stochastic models, such as the BN population stressor model, can inherently display results as probabilities of various states or potential outcomes. The spread and magnitude of probability values across the outcome states in the BN model reflect the combination of uncertainties in states across all other variables, as reflected in each of their conditional probability tables. More sophisticated means of estimating variance of the probabilities of outcome states can also be undertaken (e.g. calculating their standard deviation and standard error from bootstrapping random subsets of the input values (Guisan and Zimmermann 2000) or from random subsets of simulated output cases). These additional steps are laborious, however, and better undertaken after the BN model has been through additional peer review and established as at least a *beta* level model (see below).

The spread of probabilities among the BN outcome states is itself an expression of uncertainty and important information for the decision-maker who may wish to weigh alternative outcomes in a risk assessment. When predictions result in high probability of one population outcome state and low to zero probabilities of all other states, there is low overall uncertainty of predicted results, presuming that the other categories of uncertainty (in our understanding of the system and our representation of that understanding in the modeling) are taken into account. In some cases, however, the BN model predicts nearly equivalent probabilities of more than one population outcome state. In these cases, uncertainty of the outcomes is greater, and the decision-maker may wish to weigh the probabilities according to his or her risk attitude and decision criteria.

Finally, model uncertainty also entails addressing model credibility, acceptability, and appropriateness of the model structure. We made every effort to ensure that the model structure was appropriate and credible, and that the inputs were parameterized according to best available knowledge on polar bears and their environment. We have explored the logic and structure of our BN model through sensitivity analyses, running the model backwards from particular states to see if it returns us to the appropriate starting point, and performing particular "what if" experiments (e.g., by fixing values in some nodes and watching how values at other nodes respond). We are as confident as we can be at this point in model development that the model is performing correctly and providing outcomes that can be useful in qualitatively forecasting the potential future status of polar bears. Because the model has been structured and parameterized by only one polar bear expert, however, there are additional criteria of model validation that must be addressed through subsequent peer review and model revision (Marcot et al. 1983; Marcot 1990, 2006).

Forecasted 21st Century Polar Bear Carrying Capacity

All 10 of the GCMs we analyzed project a downward trend in sea ice extent in the 21st century (DeWeaver 2007). Those declines are paralleled by projected declines in both total and optimal polar bear habitat at all time steps (Figure 3, Durner et al. 2007). The wide range of outcomes in each region and time period represents the spread of values from the GCM model runs, even when normalized to present-day conditions. Despite the range of outcomes, however, declines in available polar bear habitat translate to lower carrying capacity for polar bears in all ecoregions at all future time steps (Figures 8, 9).

Our projected rates of decline in habitat and polar bear carrying capacity are generally slower than rates that have actually been observed during the past two decades. This is most notable in the Seasonal Ice Ecoregion where the rate of sea ice decline has been among the most profound of any in the Arctic (Meier et al. 2007). Yet, data derived from GCM forecasts appeared to suggest slow rates of future declines in the Seasonal Ecoregion (Figures 7, 9). This inconsistency in the Seasonal Ecoregion is apparently caused, at least in part, by some GCM projections that consistently put large amounts of sea ice over the continental shelf habitats in Davis Strait and Baffin Bay. Whereas the analyses of GCM outputs suggest decreases of 15-45% in sea ice cover in Hudson Bay through the next century, the same models forecast more ice remaining over the continental shelves of Davis Strait than was actually observed in that region between 1996 and 2006. Similarly, GCMs predict only a 7% decrease of sea ice in Baffin Bay by 2100. In contrast, satellite observations verify that Baffin Bay sea ice extent declined over 10% between the 1985-1995 period and the 1996-2006 period. Between those same periods the sea ice extent over the continental shelves of Davis Strait declined 51%.

The rapid rate of observed ice loss in the Seasonal Ice Ecoregion suggests that modeled persistence of ice there in the future is probably not realistic. This concept is corroborated by observations that show this ecoregion has seen as much warming as almost any other location in the Arctic (Comiso and Parkinson 2004). If anything, sea ice declines in the Seasonal Ice Ecoregion are likely to be hastened in the future if temperatures continue to increase (Stirling and Parkinson 2006). Therefore, our projected gradual declines in polar bear carrying capacity in the Seasonal Ice Ecoregion are probably optimistic and biased on the high side.

In most other regions, the differences between observed and projected ice loss are smaller, but still variable. For example, the Polar Basin Divergent Ecoregion has seen a 4.5% loss in total habitat during the observational period. The ensemble mean forecast for ice loss in the ecoregion is 9% during the next 50 years and 26% by the end of the century. In contrast, individual IUCN subpopulation areas within the Polar Basin Divergent Ecoregion were forecast to have up to 95% decline in ice habitat. Nonetheless, the range of values in our projections appears to capture a general trend of large ice losses, large losses of optimal habitat, and large losses of carrying capacity for polar bears in the Polar Basin Divergent Ecoregion.

In contrast to the Seasonal and Polar Basin Divergent Ecoregions, we forecast more modest changes in habitat and polar bear carrying capacity for the Archipelago and Polar Basin Convergent Ecoregions. These more modest habitat losses appear consistent with modest losses during the observational period and with the forecasted changes in the individual IUCN subpopulation areas. These results parallel recent sea ice observations that show minimal declines in these ecoregions (Meier et al. 2007).

Although the pattern of projected carrying capacity varied greatly among regions, the bottom line was for an overall range-wide decline in polar bear carrying capacity of between 10% and 22% by year 45 and between 20% and 37% by year 100 (Table 6, Figure 9). The carrying capacity model forecasted that polar bears could be extirpated from the Polar Basin Divergent Ecoregion as early as year 45.

Projections from this modeling approach are deterministic projections based on current estimated densities of polar bears. They depend upon the extent of the sea ice and optimal sea ice habitat only and do not account for possible changes in relative carrying capacity as the amount of ice changes. For example, if thinner ice for shorter periods of time results in more insolation penetrating the water column and greater productivity of the remaining ice habitat, carrying capacity per unit area may rise. If on the other hand, declines in the areal extent of the under ice (epontic) community, which currently provides much of the productivity in Arctic seas (Sakshaug 2004) is not compensated by benefits of increased insolation, carrying capacity could decline. More open water in summer means more new ice forming in winter, which could increase brine expulsion (Fisher et al. 2006) with a variety of potential effects on epontic productivity. Even if overall productivity increases, if the character of the sea ice is dramatically different, polar bears may be ill-suited to forage there. The carrying capacity model cannot accommodate such scenarios, nor can it account for adverse effects of stressors other than changes in sea ice extent.

Just as the carrying capacity model cannot capture possible changes in marine productivity, it also cannot capture the importance of seasonal variation in sea ice. Durner et al.

(2007) illustrated that although the annual trend in km2-months of optimal habitat is useful for comparing large scale patterns, it overlooks the importance of seasonal variation. Whereas the GCM ensemble forecasts a polar basin-wide decline of 36% in annually available optimal habitat, it suggests declines of nearly 80% during summer (Figure 13). This reflects the fact that all GCMs forecast sea ice will continue to cover the whole polar basin during the winter through most of the 21st century. So, the realized future changes in ice habitats are seasonally dependent. This is important because seasonal fluctuations in sea ice cover include changes in the location of sea ice as well as its total quantity.

Among the most substantive spatial changes is the retreat of ice from the continental shelves of the polar basin (Comiso 2002; Rigor and Wallace 2004; Belchansky et al. 2005; Holland et al. 2006; Durner et al. 2007; Ogi and Wallace 2007; Serreze et al. 2007). Hence, not only is the sea ice declining in this region on an annual basis, there will be little or no ice in the region at all in summer. The continental shelves of the polar basin are far more productive than the deep polar basin regions offshore (Pomeroy 1997; Sakshaug 2004). Observations show that polar bears spend most of their time foraging on sea-ice over shallow water (<300m deep) (Amstrup et al. 2000, 2004a; Durner et al. 2007), where it is thought that they hunt most effectively (Stirling et al. 1981; Stirling 1997). Seasonal absence of sea ice from the shelf regions of the polar basin, therefore, can be expected to have a greater effect on foraging than the annual changes in sea ice quantity might suggest.

The length of time that ice is absent from important foraging areas is another variable that our carrying capacity model cannot accommodate. Polar bears are well adapted to survive periods of food deprivation. Those adaptations that have allowed them to successfully exploit the Seasonal Ice ecoregion (Watts and Hansen 1987). There, marine productivity is high enough that polar bears can gain sufficient mass before the ice melts to sustain a long summer and autumn fast.

The polar basin, in contrast to most of the seasonal ice regions, is relatively low in productivity (Sakshaug 2004). Whereas polar bears in the Seasonal Ecoregion reach peak body weights before the ice melts in summer; polar bears in the polar basin do not reach peak body weight until late autumn or early winter (Durner and Amstrup 1996). This suggests they have a different temporal pattern of weight gain to compensate for the relatively low productivity of the polar basin seas. Polar bears in the polar basin simply need more time to reach the weight necessary to survive the winter. Another indication of the low productivity, with which polar bears contend in the polar basin, is the observation that polar bears in the polar basin reach sexual maturity later in life than they do in other portions of their range. In the polar basin, polar bears produce their first young at age six. This is in contrast to much of the Canadian Arctic where they breed for the first time at age 4 and produce their first cubs at 5 years of age (Stirling et al. 1977, 1980, 1984; Ramsay and Stirling 1982, 1988; Furnell and Schweinsburg 1984; Amstrup 2003). Polar basin bears, therefore, may not be able to accommodate extended seasonal absence of sea ice from their preferred foraging habitats. Indeed, recent analyses suggest that the length of time that ice is absent from continental shelf foraging areas may be related to certain measures of physical stature and cub survival (Rode et al. 2007) as well as a predictor of survival (Hunter et al. 2007; Regehr et al. 2007a) in polar bears of the Beaufort Sea.

As noted earlier, most GCMs project that ice will return to much of the Arctic in winter, even late in the century. This fact is reflected in the relatively modest changes in sea ice extent we report on an annual basis--the seasonal absence is to great extent masked by the recurrence of ice in winter. Our carrying capacity model therefore does not account of these seasonal aspects of sea ice change. The impact of periods of food deprivation which are too long for polar bears to accommodate is just not represented by the changes in sea ice extent expressed as km2-months. This shortcoming is another reason that the carrying capacity model likely underestimates the effects future sea ice change will have on polar bears.

Even with all of the caveats that accompany the carrying capacity modeling, however, the conclusion that polar bear populations will face major declines over large portions of their current range seems sound if the sea ice declines as predicted. The carrying capacity model suggests the greatest declines will be in the Polar Basin Divergent Ecoregion where extirpation could occur by mid-century and seems very likely by late-century. Using the recent observational sea ice record to qualify the carrying capacity projections for the Seasonal Ice Ecoregion, it seems more likely that extirpation will occur there despite the fact that that outcome was forecasted from only the GCM minimum ice projections. The carrying capacity model further suggests that polar bears, in reduced numbers, are likely to persist in the Polar Basin Convergent Ecoregion and the Archipelago Ecoregion through the end of the 21st century.

Bayesian Network Model Forecast of the 21st Century Status of Polar Bears

Next steps in the BN model development

Before we discuss outcomes of our BN model, we provide a detailed description of its current state of development and the next steps in that development. Because BN models combine expert judgment and interpretation with quantitative and qualitative empirical information, inputs from multiple experts (if available) are necessary before a model can be considered final. Due to time constraints, however, we were not able to seek and incorporate the input of multiple polar bear experts into our BN model. Therefore, the model presented here should be viewed as a first-generation "alpha" level prototype (Marcot et al. 2006). It captures and depicts judgment of one subject matter expert. It is therefore, in a general sense, an expert system (Martin et al. 2005; McCann et al. 2006), but still must be vetted through other polar bear experts.

The next model development steps, including the vetting necessary to advance development of our prototype "alpha" level model, have been described in detail by (Marcot et al. 2006), and include:

- further peer review of the alpha model by other subject-matter experts;
- reconciliation of the peer reviews by the initial expert, and updating the model to a *beta* level that incorporates the reviews;
- testing of the beta level model for accuracy with existing data (e.g., determining if it matches historic or current known conditions); and
- updating the model to the next "*gamma*" level with existing data, or even to a *delta* level through incorporation of additional validation data from new field work or new analyses if available.

Throughout this process, sensitivity testing can be used to verify model performance and structure. This framework has been used successfully for developing a number of BN models of rare species of plants and animals (Marcot et al. 2001, 2006; Raphael et al. 2001; Marcot 2006).

The next step in the development process of the polar bear BN population stressor model is the review of the current prototype by peers--in this case by other polar bear experts. The process of review of the model by other polar bear experts is akin to the peer review of a manuscript sent to a journal. The initial model engineer can serve as an "editor" to present the alpha-level model to one or more other experts in the field; to elicit and compile their critique and comments on overall model structure (the variable used and their connections) and probabilities; and then to return to the initial expert with the reviews. The review by peers could result in revision of the alpha-level model, producing a variant(s) of the model that more adequately represents the reviewer's own expert knowledge and judgment. The initial expert develops a "reconciliation" of the reviews that annotates how each review comment was addressed in modifying the model (or not). The result is modification, or perhaps retention, of the alpha-level model structure, to produce the beta-level model which incorporates inputs from more than one expert. Model variants that may have emerged in the review process would represent the range of expert opinions and experiences, and this range could be important information for decision-making.

Further advancing of the model beyond a beta-level, depends on whether new analysis results or new empirical data are available. Because BN models are best viewed as working tools useful to project outcomes, and to guide monitoring and data collection this becomes an interactive process. The model sensitivities can indicate which monitoring efforts will provide the information most useful to future decisions. The full model or portions of the model can be tested for performance against new data generated by that monitoring. The model is then validated and updated. This advantage of the BN modeling approach which allows new field data or new empirical observations to be incorporated into the model as they come along, allows for continual tests of model performance and provide new inputs which can be, in turn, used to improve model performance. Every new piece or data and new relevant observation allows further refinement of the performance of the model (Marcot 2006).

Because these additional steps in development of our prototype model have not yet been completed, it is important to view probabilities of outcome states in terms of their general direction and overall magnitudes rather than focusing on the exact numerical probabilities of the outcomes. When predictions result in high probability of one population outcome state and low or zero probabilities of all other states, there is low overall uncertainty of predicted results. When projected probabilities of various states are more equally distributed, however, careful consideration should be given to large nonzero probabilities representing particular outcomes even if those probabilities are not the largest. Consistency of pattern among scenarios (e.g., different GCM runs) also is important to note. If the most probable outcome has a much higher probability than all of the other states, and if the pattern across time frames and GCM models is consistent, it is most likely important to note that outcome and pattern. If on the other hand, probabilities are more uniformly spread among different states, and if the pattern varies among scenarios, the importance of the most probable outcome may not be as great. This approach takes advantage of the information available from the model while recognizing that it is still in development. It also conforms to the concept of viewing the model as a tool describing relative probabilistic relationships among major levels of population response under multiple stressors.

BN model projected outcomes

In the BN model, for each scenario run, the spread of population outcome probabilities (or at least non-zero possibilities) represented how individual uncertainties propagate and compound across multiple stressors. Beyond year 45, "extinct" was the most probable state into which polar bear populations in all ecoregions moved, except those in the Archipelago Ecoregion (Figure 10, Table 8).

Distribution changes driven by changes in the sea ice appeared to be a major factor leading to these predictions. The sea ice extents of the Polar Basin Divergent Ecoregion and Seasonal Ice Ecoregion have declined more rapidly than other places in the Arctic (Meier et al. 2007). The loss of sea ice habitats in the Polar Basin Divergent Ecoregion is projected to continue, and possibly to accelerate (Holland et al. 2006; Stroeve et al. 2007; Durner et al. 2007). Because polar bears are tied to the sea ice for obtaining food, major changes in the quantity of and distribution of sea ice must result in similar changes in polar bear distribution. In this sense, our carrying capacity model incorporates an element of foraging efficiency, even though it cannot directly account for other potential stressors per se.

The BN model suggested that polar bear populations in the Seasonal Ice Ecoregion moved into the extinct category rapidly in contrast to outcomes projected by the carrying capacity model. This may have been because the BN model incorporated aspects of the spatiotemporal distribution of the sea ice that are consistent with recent analyses (Hunter et al. 2007; Regehr et al. 2007a) suggesting that long periods without ice habitats over continental shelf foraging areas may be associated with decreased survival of polar bears. In addition to variables representing the availability of sea ice over the continental shelves, our BN model incorporated other potential stressors not included in our projection of carrying capacity which could have resulted in the different forecasts for the Seasonal Ice Ecoregion. The BN model projection for the Seasonal Ice Ecoregion also seems more in line with the observational record (Stirling and Parkinson 2006; Meier et al. 2007) and provides added cause for reconsideration of the results of the carrying capacity model in the Seasonal Ice Ecoregion.

Overall outcomes projected for polar bears appeared to be driven more by distributional effects than numerical effects. The most probable outcomes for Factor A (Habitat Threats) of the Proposal to list polar bears as a threatened species were "major restriction" (Table 10). Numerical responses of polar bears to future circumstances were forecast to be more modest than changes in distribution. In all regions, reduced density was the most probable outcome (Table 9). One way to interpret that outcome may be that where habitat remains, polar bears will remain even if in reduced numbers. This is consistent with our BN model results suggesting that polar bear populations may remain in the Archipelago Ecoregion at least into the middle of the 21st century. Corresponding with our carrying capacity projection, declines in distribution and number are likely to be faster and more profound in the Polar Basin Divergent Ecoregion and the Seasonal Ecoregion than elsewhere. Importantly, our results suggest that a core of polar bear habitat and some number of polar bears is likely to persist in and around the Archipelago Ecoregion at least into mid century.

Sensitivity analyses

Sensitivity analyses offer an opportunity to interpret model outcomes at every level. The overall population outcome was most sensitive to change in habitat quantity (node B) and temporal habitat availability (node C). The other major habitat variable, change in distance between ice and the continental shelf (node N) was the 6th most influential factor on the overall population outcome. Change in distance between ice and the continental shelf may have been ranked much lower than the other two quantitative sea ice variables because it was a measurement which only applied to the two polar basin ecoregions. This variable was not calculated in the Archipelago or Seasonal Ice Ecoregions because waters there are all (or essentially all) over the continental shelf. Nonetheless, the combination of these three habitat variables explained 64% of the uncertainty in the overall population outcome. Ecoregion was the 3rd most influential node on overall outcome. We constructed the model recognizing that the four ecoregions differed in the nature of the sea ice which occurred there and in how polar bears utilize that ice. The fact that ecoregion explained 15% of the variation in overall population outcome is further evidence of the importance of sea ice habitat and its regional differences, to polar bear responses to projected habitat change. This is an important result helpful in understanding that, for example, polar bears appear to be facing much greater restriction in the Polar Basin Divergent and Seasonal Ice ecoregions than they do elsewhere.

Another habitat variable, "sea ice character" (node S1), was ranked 5th among variables having influence on the overall population outcome. This qualitative variable relating to sea ice character was included to allow for the fact that in addition to changes in quantity and distribution of sea ice, more subtle changes in the sea ice could affect polar bears. For example, longer open water periods and warmer winters have resulted in thinner ice in the polar basin region (Lindsay and Zhang 2005; Holland et al. 2006; Belchansky et al. 2008). Fischbach et al. (2007) hypothesized that thinning and the associated greater extent of marginal ice stability in autumn has resulted in reduced sea ice denning among polar bears of the southern Beaufort Sea.

Observations during polar bear field work suggest that the thinning of the sea ice also has resulted in increased roughness and rafting among ice floes. Compared to the thicker ice that dominated the polar basin decades ago, thinner ice is more easily deformed, even late in the winter. Although highly deformed ice composed of blocks of thin and rafted ice may be satisfactory for seals, they may not be well suited to polar bear foraging. These changes appear to reduce foraging effectiveness of polar bears and it is suspected the changes in ice conditions may have contributed to recent cannibalism and other unusual foraging behaviors (Stirling et al. 2008).

Recognizing these recent observations of nutritionally stressed individuals prompted us to include the "sea ice character" variable to qualitatively summarize a variety of changes in sea ice which may affect polar bears. States for this variable were entered based upon the observations that habitat quality already had been changing in a negative way in the Polar Basin Divergent Ecoregion. States, however, were entered differently to reflect that warming which has caused thinning of ice in the polar basin, could actually improve habitat for polar bears in other ecoregions. That flexible parameterization resulted in this variable explaining 6% of the variation in overall population outcome. The sensitivity of overall population outcome to this node confirms that the nature of the sea ice as well as its spatiotemporal distribution will continue to have an important influence on the future of polar bears.

The 4th ranked potential stressor to which overall population outcome was sensitive was intentional takes. Historically, the direct killing of polar bears by humans, for subsistence or for sport, has been the biggest challenge to polar bear welfare (Amstrup 2003). Our model suggests that harvest of polar bears remains an important factor in their population dynamics, as sea ice retreats. Retreating sea ice will make the arctic habitats of polar bears more accessible and it is likely to result in increased numbers of bears occupying terrestrial habitats, at least seasonally. These factors will increase the potential vulnerability of bears to direct human kills. As the regions of the Arctic, which are currently unsettled due to the harshness of the climate, become warmer, human settlements and developments are likely to expand into them. This will increase the likelihood of takes in areas where direct mortalities by humans had not previously been an issue. The fact that intentional takes ranked so importantly in our outcomes suggests that of the potential human effects on polar bears, management of hunting will continue to be important (but see below).

The remainder of the variables ranking in the top ten with regard to their influence on overall population outcome were bear-human interactions (node B1), parasites and disease (node T), and hydrocarbon contamination (node R4). Although these and the remainder of the variables which exerted influence on overall outcome cumulatively explained only 9% of the variation in outcome, some of them result directly from human behavior. Hence, noting their influence may be of management value. Bear-human interactions, number 7 on the list of factors to which overall outcome was sensitive, are likely to increase as bears lose their traditional sea ice habitats. Our direct observations indicate these interactions already are increasing in Alaska as larger numbers of bears remain on land in summer. Longer summers They also have increased in frequency in portions of the Seasonal Ice Ecoregion where increased periods of ice absence have resulted in more bears in poor condition appearing in settlements as they apparently seek alternate foods (Regehr et al. 2007b). According to our model, management of bear-human interactions could influence the future status of polar bears at least on the local level.

The influence of parasites and disease agents, number 8 on the sensitivity list, on polar bears would likely increase if the climate continues to warm. Historically, polar bears have had few parasite and disease agents with which to contend (Amstrup 2003) but this may change as warming continues. Parasitic agents which have developmental stages outside the bodies of warm-blooded hosts (e.g., nematodes) will likely benefit from the warmer and wetter weather forecast for the Arctic (Macdonald et al. 2005). Improved conditions for such parasites already have had significant impacts on some terrestrial mammals (Kutz et al. 2001, 2004). Bacterial parasites also are likely to benefit from a warmer and wetter Arctic. In general, the distribution and abundance of a variety of pathogens is dependent upon climate influences (Dobson and Carper 1993; Powell et al. 1996; Cook et al. 1998). Although increases in disease and parasite agents have not yet been reported in polar bears, a warming climate has been associated with increases in pathogens in a variety of other marine organisms (Kuiken et al. 2006). Similar increases in disease and parasite agents in the polar bear's environment are anticipated, however, if temperatures continue to warm as projected.

Human activities related to oil and gas exploration and development are very likely to increase with disappearance of sea ice from many northern areas. At the same time, less sea ice will facilitate offshore developments. More offshore development will increase the probability of hydrocarbon discharges into polar bear environments (Stirling 1990). The record of over 30 years of oil and gas development in Alaska suggests that with proper management, potential negative effects of these activities on polar bears can be minimized (Amstrup 1993, 2000, 2003; Amstrup et al. 2004b). Increases in marine developments, however, and the associated increases in shipping (etc.) will require new monitoring methods and may require increased diligence to maintain the positive track record. Hence, restricted sea ice could lead to greater probabilities of localized contaminant discharges.

Long range marine and atmospheric transport of contaminants also is likely to increase (Macdonald et al. 2003, 2005). Increased rainfall in northern regions already has increased river discharges into the arctic seas. Many of these north flowing rivers originate in heavily industrialized regions and carry heavy contaminant burdens (Macdonald et al. 2005). Considering the potential for increases in both local and long range transport of contaminants to the arctic, with warmer climate and less sea ice, the influence these activities have on polar bears is likely to increase.

Strength of evidence of BN model projections

The overall outcomes projected by our BN population stressor model are consistent with conclusions of the International Union for the Conservation of Nature (IUCN) polar bear specialist group (PBSG) which recommended, based mainly on projected changes in sea ice, that polar bears should be reclassified as vulnerable (Aars et al. 2006). It is also consistent with the increasing volume of data confirming negative relationships between polar bear welfare and sea ice decline (Stirling and Derocher 1993; Stirling et al. 1999, 2007, 2008; Ainley et al. 2003; Derocher et al. 2004; Ferguson et al. 2005; Aars et al. 2006; Amstrup et al. 2006; Stirling and Parkinson 2006; Hunter et al. 2007). In summary, our prototype BN population stressor model projects that sea ice and sea ice related factors will be the dominant driving force affecting future distributions and numbers of polar bears through the 21st century. Our model also projects that if sea ice patterns change as projected by currently available climate models, polar bears will be absent from 2 major portions of their range by mid century.

Despite caveats regarding the early stage of development of our BN model, there are reasons, in addition to its consistency with the conventional wisdom of the polar bear community, to believe the directions and general magnitudes of its outcomes are reasonable. Sea ice related variables, including our 3 nodes (B, C, and N) which were derived from GCM outputs, were in the top 6 variables to which overall outcome was sensitive, and explained 70% of the variation in that outcome (Figure 12, Appendix 1). This, while appearing to corroborate the well established link between polar bears and sea ice, prompted us to ask 2 questions. First, is there is anything that humans could do, short of bringing back more ice, that would qualitatively alter our projected outcomes. Second, how much different would sea ice need to be to cause a qualitative change in our overall outcomes.

Could on the ground management affect our outcomes?--To address the first question, we fixed the input states for all nodes over which humans might be able to exert control (e.g., harvest, contaminants, oil and gas development) first to same as now, and then to improved conditions as compared to now. We reran the BN population stressor model under both conditions for other nodes and at all future time periods and with all 3 GCM scenarios for sea ice.

Despite fixing human influences, outcomes of these runs were not qualitatively different from previous runs for the Polar Basin Divergent and Seasonal Ecoregions. Projected probabilities of extinction were lower at every time step, but the most probable outcome state for these two ecoregions was still "extinct" at nearly every time step and for every GCM scenario. The only exception to this statement was for the Seasonal Ecoregion at year 45, the most probable outcome from the maximum ice GCM scenario being "smaller" rather than "extinct." In that case, however, the probability of extinct was just slightly below that of smaller. Probabilities of extinction in these two fixed runs of the model were lower at each time step and for each GCM scenario than during the general runs of the model (Figure 14), indicating that more probability was being spread across other outcome states (Table 14). However, at all time steps (except for year 45 in the Seasonal Ice Ecoregion), the predicted probability of extinction was around twice that of any other outcome state. The conclusion for the Seasonal Ice and Polar Basin Divergent Ecoregions is that management of localized human activities can have no qualitative effect on the future of polar bears in the Seasonal Ice and Polar Basin Divergent Ecoregions if sea ice continues to decline as projected. Polar bears of both ecoregions are projected to move toward extinction by 45 years from now.

There were greater differences between our fixed runs and our general runs in the other ecoregions. The most probable outcome state for the Archipelago Ecoregion was smaller at all time steps and for all GCM scenarios when human factors were set to same as now. When human factors were set to fewer than now, the most probable state of the Archipelago Ecoregion was same as now through the 45 year time step and smaller thereafter. Probabilities of other outcome states in the Archipelago Ecoregion were rather evenly distributed on either side of the "smaller" outcome (Table 14). Probabilities of extinction were substantially lower than in our general model runs when human influences were either same as now or better then now, and with the GCM maximum scenario they were essentially 0 through year 75 (Figure 14). Also, there was even a relatively large probability of increase in some of the runs. This indicates that management of human factors could be important for polar bears in the Archipelago Ecoregion.

In the Polar Basin Convergent Ecoregion, "smaller" rather than "extinct" was the most probable outcome at year 45 for all GCM scenarios when human factors were either same as now or improved. Under the scenario where human factors were fixed as fewer in the Polar Basin Convergent Ecoregion, "smaller" was the most probable outcome through year 75 in the maximum GCM scenario. Probabilities of extinction were lower (Figure 14), and probabilities were spread through other outcome states. Unlike the Archipelago Ecoregion, however, extinct was the most probable outcome at most time steps for the majority of GCM scenarios (Table 14, Figure 14).

The conclusion from these fixed runs of the model is that management of human activities has the potential to qualitatively improve the welfare of polar bears in the Archipelago Ecoregion through the 21st century and in Polar Basin Convergent Ecoregion through mid-century. Conversely, it appears that there is little that management of localized human activities can do, assuming spatiotemporal extent of the sea ice continues to decline as expected, to qualitatively improve the outcomes projected for polar bears in the Polar Basin Divergent and Seasonal Ice Ecoregions. Polar bears in those two ecoregions, which include approximately 2/3 of the current range-wide population, are projected to become extinct by mid century regardless of local management actions that would eliminate or mitigate anthropogenic stressors.

Could future sea ice be different enough to affect outcomes?--Fixing the effects in our model, which humans might be able to manage, illustrated that sea ice effects prevail in determining the future of polar bears, and that only in some regions could those effects be compensated by on the ground human activities. But what would it take in the way of different sea ice projections to qualitatively change our forecasted population outcomes? To answer that question we must turn to the presumptions built into our model.

We populated the conditional probability tables, in nodes of our model which reflect sea ice extent and distribution, in recognition of the established reliance of polar bears on the surface of the sea ice (Table 3, Appendix 3). Evidence for the polar bear's reliance on sea ice is replete. Although they are opportunistic and will take terrestrial foods, including human refuse, when available, and may benefit from such activity (Lunn and Stirling 1985; Derocher et al. 1993), polar bears are largely dependent on the productivity of the marine environment. Refuse, for example, is of limited availability throughout the polar bear range, and could at best benefit relatively few individuals. Also, polar bears are poorly equipped to consume and digest most plant parts (Chapin et al. 2006), and they are, for the most part, inefficient in preying on terrestrial animals (Brook and Richardson 2002; Stempniewicz 2006). Perhaps most importantly, polar bears have evolved a strategy designed to take advantage of the high fat content of marine mammals (Best 1984). Available terrestrial foods are, with few exceptions, not rich enough or cannot be gathered efficiently enough to support polar bears, which are the largest of the bears, in any numbers (Welch et al. 1997; Rode et al. 2001; Robbins et al. 2004). Although there are localized exceptions, polar bears appear to gain little overall benefit at the population level, from alternate foods (Ramsay and Hobson 1991). Polar bears, it appears, are obligately dependent on the surface of the sea ice for capture of the prey necessary to maintain their populations.

Based upon this well established reliance on sea ice for foraging we assumed that continued declines, in regions where sea ice declines already have had significant deleterious effects, would be negative for polar bears and we built that assumption into the conditional probability tables of our models. We also assumed that in some ecoregions, polar bears might benefit from changes in the sea ice - at least temporarily - or would at least not be as greatly affected as in other regions. We built that assumption into our models as well. These assumptions, in short, mean that if sea ice continues to decline it ultimately will have a negative effect on polar bears but that those effects will not be equal in all ecoregions nor will they occur at the same times in all regions.

So, the question "how would the ice need to change in order to produce outcomes qualitatively different than our current model outcomes (Table 8 and figures 10 and 11)" is reasonable. We explored this question in our BN model by setting the values for all non-ice inputs to uniform prior probabilities. That is we didn't make any assumptions about whether they would change in ways that were better or worse for polar bears. We assumed complete uncertainty with regard to future food availability, oil and gas activity, contaminants and disease etc. Then, we ran the model to determine how changes in the sea ice states alone, specified by our ensemble of GCMs, given complete uncertainty with regard to all else, would affect our outcomes.

This exercise illustrated that for the Seasonal Ice Ecoregion, and the Polar Basin Divergent Ecoregion, sea ice would have to decline substantially less than is predicted by our maximum ice GCM scenario to make any qualitative difference in our outcomes. At all time steps and for all GCM runs, the most probable outcome is "extinct" (Figure 14), and by far the greatest probability falls into the extinct state (Table 15). The most probable outcome in the Polar Basin Convergent Ecoregion also is "extinct" at all time steps under this fixed modeling situation. Overall probabilities of extinction are lower, and more probability is forecast for other outcome states, but extinction holds more than twice the probability of any other state at all time frames. We do not know just how much more ice it would take to prevent this outcome, but it would need to be much more than any of our models suggest if it were to result in a qualitative improvement of the general model outcome.

Even in the Archipelago Ecoregion there is no substantial change. There, the most probable outcomes are in the same patterns as in our general model runs. The difference is that the probability of extinct is slightly lower in most cases, and more probability is spread throughout other possible states.

In conclusion, to see any qualitative change in the probability of extinction in any of the ecoregions, even in year 45, sea ice projections would need to leave more sea ice than the maximum GCM projection we used. This eventuality may be unlikely in light of the fact, as shown in Figures 3, 6, and 7, that most sea ice models tended to predict more ice than there actually was during the observational record between 1979 and present (Durner et al. 2007; Stroeve et al. 2007). It also may seem unlikely in light of recent observations. As of 23 August 2007 declines in Arctic sea ice extent in 2007 have set a new record for the available time series from 1979-2006. This record minimum is 400,000 km2 below the previous record which occurred in 2005 (National Snow and Ice Data Center, http://nsidc.org/news/press/2007_seaice minimum/20070810_index.html). Because this new record has occurred 25-83 days before the summer melt season will end in different parts of the polar basin (Stroeve et al. 2006), much more melting and greater sea ice reduction seems likely. The more rapid decline in observed sea ice than in modeled sea ice (Stroeve et al. 2007) appears to be continuing. By exploring outcomes of our BN model by fixing certain parameters, we determined that future sea ice would have to be more extensive, at all time steps, than is projected by our most conservative models (the models forecasting the most sea ice remaining). But, the sea ice in 2007 already has declined below the level projected for mid century by the 4 most conservative models in our ensemble (Figure 15). This seems to be compelling evidence that we are not likely to see more ice than our models have suggested at any of the future time steps we evaluated.

Another aspect of the 2007 summer ice melt is pertinent to our discussion. Our analyses of GCM outputs has suggested that sea ice is likely to remain in the Archipelago Ecoregion through the end of the century. Based upon this projection, our carrying capacity model and our BN model both suggested that the Archipelago Ecoregion would provide refuge to polar bears well into the century. The southern portion of the Archipelago Ecoregion, however, was clear of sea ice by 23 August 2007 (Figure 15). This recent observation then calls into question a main conclusion of our modeling effort: that polar bears in the Archipelago Ecoregion may be insulated from sea ice change for many decades. True, this is just one yearly data point. But it is a data point that fits a recent pattern of sea ice declining at an accelerating rate that is faster than sea ice forecasters have projected. And, it is one piece of evidence suggesting that it may not be at all reasonable to expect that future spatiotemporal distribution of sea ice will exceed the maximum values projected by our model ensemble.

We do not know how other polar bear experts might differ in how they would structure and parameterize a BN polar bear population stressor model. Several factors, however, suggest that a polar bear model would have to be structured and parameterized very differently to project qualitatively different outcomes. First, the great sensitivity in our model to sea ice habitat changes is consistent with hypothesized effects of global warming on polar bears (Derocher et al. 2004). Second, this sensitivity to sea ice change parallels recent observations of how decreasing spatiotemporal distribution of sea ice has affected polar bears (Stirling et al. 1999, 2007; Hunter et al. 2007; Regehr et al. 2007a, 2007b; Rode et al. 2007). Third, it appears that future sea ice patterns would have to be fundamentally different than is projected for the apparent direction in polar bear populations we project to be altered. Finally, with sea ice trends continuing to decline at rates that are faster than forecast, the relationship of polar bears to sea ice change would have to be fundamentally different than the range-wide body of polar bear data suggests it is. All of these would have to be very different for trends in polar bears distrubution and numbers to take a fundamentally different path than our BN model projects.

In short, although it is highly likely that other polar bear experts might structure a model differently and populate conditional probability tables differently than we have, it seems unlikely that those differences would be great enough to make a qualitative difference in the outcomes projected by our prototype model.

Conclusion

We took two approaches to forecast the range-wide future status of polar bears. First, we built a simple deterministic model of future polar bear carrying capacity. This model depended on a linear relationship between sea ice area and polar bear density. It was easy to understand and provided some sense of how numbers of polar bears might change over time in different regions of the Arctic. However, because it only addressed annual average sea ice extent, the carrying capacity model could not account for contribution of changes in the nature or spatiotemporal distribution of sea ice. It also could not account for other population stressors which could accompany changes in the sea ice and which could exacerbate the effects due to habitat loss. Hence, this simple deterministic model provided a conservative outlook for polar bears. Second, we built a Bayesian network population stressor (BN) model. This model incorporated changes in spatiotemporal distribution of sea ice as well as other potential population stressors which the deterministic carrying capacity model did not include. The BN model incorporated quantitative information regarding changes in habitat as well as qualitative information regarding other potential stressors in a probabilistic setting. The BN model had the ability to more thoroughly assess the extent of changes which might occur and to describe outcome states in terms of their relative probabilities.

Our forecasts suggested that declines in the spatiotemporal distribution of sea ice habitat along with other potential stressors will severely impact future polar bear populations. Outcomes varied geographically and by time step, and included the following:

1. Polar bear populations in the Polar Basin Divergent and Seasonal Ice ecoregions will most likely be extirpated by mid century. Approximately 2/3 of the world's current polar bear population resides in the combined area of these two ecoregions.
2. Polar bear populations in the Archipelago Ecoregion appear likely to persist through the middle of the century. Some modeling scenarios suggest persistence of polar bears in this ecoregion toward the end of the century. The number of bears in this ecoregion will likely be less than at present due to the reduced amount of habitat and other factors.
3. Polar bears in the Polar Basin Convergent Ecoregion may persist through mid-century, but they most probably will be extirpated at and beyond year 75.
4. A declining habitat base, coinciding with FWS Listing Factor A (habitat threats), was the overriding factor in forecasts of declining numbers and distribution of polar bears.
5. Other factors which correspond with FWS listing Factors B, C, and E, and which could result in additional population stress on polar bears, are likely to exacerbate effects of habitat loss.
6. Management of localized human activities such as hunting, release of contaminants, and direct bear-human interactions etc., qualitatively increased the probability of persistence of polar bears in the Archipelago ecoregion through the end of the century and increased the probability that polar bears could persist in the Polar Basin Convergent Ecoregion through mid-century.
7. Management of localized human activities did not appear able to change the probability of extinction in the Polar Basin Divergent or Seasonal Ice ecoregions in any qualitative way. Holding all model inputs for localized human activities to represent fewer impacts than now made no qualitative change in the probability of extinction.
8. Because recently observed declines in sea ice extent continue to outpace most GCM projections, more extensive sea ice seems an increasingly unlikely future. Yet, to qualitatively alter outcomes projected by our models and head off the projected loss of 2/3 of the world's current polar bears, future sea ice would have to be far more extensive than is projected by even conservative General Circulation Models.

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Table 1. Ten IPCC AR-4 GCMs whose sea ice simulations and projections were used to define ice covariates for polar bear RSF models: IPCC model ID, country of origin, approximate grid resolution (degrees), forcing scenario, and the number of runs used for the polar bear studies.

We treated the mean of the 8 ncar_ccsm3_0 model runs as a single output to be consistent with the other models which had only one run.

MODEL ID	Country	Grid Resolution (lat x lon)	Forcing Scenario	Number of Runs
ncar_ccsm3_0	USA	1.0 x 1.0	20c3m	8
			SRES A1B	8
cccma_cgcm3_1	Canada	3.8 x 3.8	20c3m	1
			SRES A1B	1
cnrm_cm3	France	1.0 x 2.0	20c3m	1
			SRES A1B	1
gfdl_cm2_0	USA	0.9 x 1.0	20c3m	1
			SRES A1B	1
giss_aom	USA	3.0 x 4.0	20c3m	1
			SRES A1B	1
ukmo_hadgem1	UK	0.8 x 1.0	20c3m	1
			SRES A1B	1
ipsl_cm4	France	1.0 x 2.0	20c3m	1
			SRES A1B	1
miroc3_2_medres	Japan	1.0 x 1.4	20c3m	1
			SRES A1B	1
miub_echo_g	Germany/Korea	1.5 x 2.8	20c3m	1
			SRES A1B	1
mpi_echam5	Germany	1.0 x 1.0	20c3m	1
			SRES A1B	1

Table 3. Input data used in the Bayesian network population stressor model (Figure 5).

Data for model node B was derived from the spreadsheet carrying capacity model (Table 6); data for model nodes C and N were derived from the global circulation model (GCM) results; and data for all other model nodes were specified as best professional judgment by one polar bear expert (S. Amstrup).

	BBN node name	B	C	N	S1	M	R3	R2	F
	Variable name	Foraging habitat quantity change	Foraging habitat absence change	Shelf distance change	Foraging habitat character	Geographic area	Alternative prey availability	Relative ringed seal availability	Alternative regions available
	Unit of measure	% change from "now"	# of Months Different than now	km	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	any value < or = +20%	any value > or = -1	any value > or = -200	more_optimal same_as_now less_optimal	Polar_Basin_Divergent Polar_Basin_Convergent Archipelago Seasonal_Ice	increase same_as_now decrease	increase same_as_now decrease	Yes No
Time Period	**Basis**								
					Seasonal Ice Ecoregion				
Year -10	Satellite data	17.14%	-0.7	*	more_optimal	Seasonal_Ice	decrease	increase	Yes
Year 0	Satellite data	0.00%	0.0	*	same_as_now	Seasonal_Ice	same_as_now	same_as_now	Yes
Year 45	GCM minimum	-10.36%	1.0	*	same_as_now	Seasonal_Ice	decrease	decrease	Yes
Year 75	GCM minimum	-31.89%	2.5	*	less_optimal	Seasonal_Ice	decrease	decrease	Yes
Year 100	GCM minimum	-32.11%	2.7	*	less_optimal	Seasonal_Ice	decrease	decrease	Yes
Year 45	Ensemble mean	-14.62%	1.0	*	same_as_now	Seasonal_Ice	decrease	decrease	Yes
Year 75	Ensemble mean	-25.75%	1.6	*	less_optimal	Seasonal_Ice	decrease	decrease	Yes
Year 100	Ensemble mean	-27.83%	1.8	*	less_optimal	Seasonal_Ice	decrease	decrease	Yes
Year 45	GCM maximum	-6.71%	0.7	*	same_as_now	Seasonal_Ice	decrease	decrease	Yes
Year 75	GCM maximum	-21.16%	1.3	*	same_as_now	Seasonal_Ice	decrease	decrease	Yes
Year 100	GCM maximum	-21.69%	1.7	*	same_as_now	Seasonal_Ice	decrease	decrease	Yes

Table 2. Composite summary categories of polar bear carrying capacity change from present levels, based on categories of composite habitat change and composite carrying capacity change.

Composite habitat change summary category	Composite carrying capacity change summary category	Composite summary category of carrying capacity change
Expanding fast	Increasing high	Enhanced
Expanding fast	Increasing moderate	Enhanced
Expanding fast	Stable	Enhanced
Expanding moderate	Increasing high	Enhanced
Expanding moderate	Increasing moderate	Enhanced
Expanding moderate	Stable	Enhanced
Stable	Decreasing high	Decreased
Stable	Decreasing moderate	Decreased
Stable	Decreasing low	Decreased
Stable	Increasing high	Enhanced
Stable	Increasing moderate	Enhanced
Stable	Stable	Maintained
Contracting slow	Decreasing high	Decreased
Contracting slow	Decreasing moderate	Decreased
Contracting slow	Decreasing low	Decreased
Contracting slow	Stable	Decreased
Contracting moderate	Decreasing high	Toward extirpation
Contracting moderate	Decreasing moderate	Decreased
Contracting moderate	Decreasing low	Decreased
Contracting moderate	Stable	Decreased
Contracting fast	Decreasing high	Toward extirpation
Contracting fast	Decreasing moderate	Toward extirpation
Contracting fast	Decreasing low	Decreased
Contracting fast	Stable	Decreased

Table 3. continued.

	BBN node name	J1	B1	R1	J	R4	T1	E	T	T2
	Variable name	Tourism	Bear-human interactions	Oil & gas activity	Shipping	Hydrocarbons / oil spill	Contaminants	Intentional takes	Parasites & disease	Predation
	Unit of measure	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	increased same_as_now decreased	increased same_as_now decreased	increase no_change decrease	increased same_as_now	increased_occurrence same_as_now decreased_occurrence	elevated same_as_now reduced	increased same_as_now decreased	influential not	influential not
Time period	**Basis**									
	Seasonal Ice Ecoregion									
Year -10	Satellite data	decreased	decreased	no_change	same_as_now	same_as_now	reduced	decreased	not	not
Year 0	Satellite data	same_as_now	same_as_now	no_change	same_as_now	same_as_now	same_as_now	same_as_now	not	not
Year 45	GCM minimum	increased	increased	no_change	increased	same_as_now	elevated	decreased	influential	influential
Year 75	GCM minimum	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM minimum	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	Ensemble mean	increased	increased	no_change	increased	same_as_now	elevated	decreased	influential	influential
Year 75	Ensemble mean	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	Ensemble mean	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	GCM maximum	increased	increased	no_change	increased	same_as_now	elevated	decreased	influential	influential
Year 75	GCM maximum	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM maximum	increased	increased	no_change	increased	increased_occurrence	elevated	decreased	influential	influential

Table 3 continued.

	BBN node name	B	C	N	S1	M	R3	R2	F
	Variable name	Foraging habitat quantity change	Foraging habitat absence change	Shelf distance change	Foraging habitat character	Geographic area	Alternative prey availability	Relative ringed seal availability	Alternative regions available
	Unit of measure	% change from "now"	# of Months Different than now	km	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	any value < or = +20%	any value > or = -1	any value > or = -200	more_optimal same_as_now less_optimal	Polar_Basin_Divergent Polar_Basin_Convergent Archipelago Seasonal_Ice	increase same_as_now decrease	increase same_as_now decrease	Yes No
Time Period	**Basis**								
					Archipelago Ecoregion				
Year -10	Satellite data	3.21%	-0.5	*	less_optimal	Archipelago	same_as_now	decrease	No
Year 0	Satellite data	0.00%	0.0	*	same_as_now	Archipelago	same_as_now	same_as_now	No
Year 45	GCM minimum	-13.79%	1.1	*	more_optimal	Archipelago	increase	increase	No
Year 75	GCM minimum	-20.71%	2.0	*	same_as_now	Archipelago	decrease	decrease	No
Year 100	GCM minimum	-24.30%	2.3	*	same_as_now	Archipelago	decrease	decrease	No
Year 45	Ensemble mean	-11.93%	1.5	*	more_optimal	Archipelago	increase	increase	No
Year 75	Ensemble mean	-20.06%	2.4	*	same_as_now	Archipelago	increase	decrease	No
Year 100	Ensemble mean	-22.16%	2.5	*	same_as_now	Archipelago	decrease	decrease	No
Year 45	GCM maximum	-3.43%	0.0	*	more_optimal	Archipelago	increase	increase	No
Year 75	GCM maximum	-18.02%	2.7	*	more_optimal	Archipelago	increase	increase	No
Year 100	GCM maximum	-20.85%	2.3	*	same_as_now	Archipelago	decrease	decrease	No

Table 3 continued.

	BBN node name	J1	B1	R1	J	R4	T1	E	T	T2
	Variable name	Tourism	Bear-human interactions	Oil & gas activity	Shipping	Hydrocarbons / oil spill	Contaminants	Intentional takes	Parasites & disease	Predation
	Unit of measure	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	increased same_as_now decreased	increased same_as_now decreased	increase no_change decrease	increased same_as_now	increased_occurrence same_as_now decreased_occurrence	elevated same_as_now reduced	increased same_as_now decreased	influential not	influential not
Time period	**Basis**									
					Archipelago Ecoregion					
Year -10	Satellite data	decreased	increased	no_change	same_as_now	same_as_now	reduced	same_as_now	not	not
Year 0	Satellite data	same_as_now	same_as_now	no_change	same_as_now	same_as_now	same_as_now	same_as_now	not	not
Year 45	GCM minimum	increased	increased	no_change	same_as_now	same_as_now	elevated	increased	influential	not
Year 75	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	same_as_now	influential	influential
Year 100	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	Ensemble mean	increased	increased	no_change	same_as_now	same_as_now	elevated	increased	influential	not
Year 75	Ensemble mean	increased	increased	increase	same_as_now	increased_occurrence	elevated	same_as_now	influential	influential
Year 100	Ensemble mean	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	GCM maximum	increased	increased	no_change	same_as_now	same_as_now	elevated	increased	influential	not
Year 75	GCM maximum	increased	increased	increase	same_as_now	increased_occurrence	elevated	increased	influential	not
Year 100	GCM maximum	increased	increased	increase	same_as_now	increased_occurrence	elevated	decreased	influential	influential

Table 3 continued.

Time Period	Basis	B	C	N	S1	M	R3	R2	F
	BBN node name	B	C	N	S1	M	R3	R2	F
	Variable name	Foraging habitat quantity change	Foraging habitat absence change	Shelf distance change	Foraging habitat character	Geographic area	Alternative prey availability	Relative ringed seal availability	Alternative regions available
	Unit of measure	% change from "now"	# of Months Different than now	km	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	any value < or = +20%	any value > or = -1	any value > or = -200	more_optimal same_as_now less_optimal	Polar_Basin_Divergent Polar_Basin_Convergent Archipelago Seasonal_Ice	increase same_as_now decrease	increase same_as_now decrease	Yes No
Polar Basin Divergent Ecoregion									
Year -10	Satellite data	5.33%	-0.3	-83	more_optimal	Polar_Basin_Divergent	same_as_now	increase	Yes
Year 0	Satellite data	0.00%	0.0	0	same_as_now	Polar_Basin_Divergent	same_as_now	same_as_now	Yes
Year 45	GCM minimum	-36.15%	2.1	1359	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 75	GCM minimum	-44.64%	2.9	2006	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 100	GCM minimum	-49.46%	3.2	2177	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 45	Ensemble mean	-19.31%	1.8	631	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 75	Ensemble mean	-31.68%	2.6	1034	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 100	Ensemble mean	-35.77%	3.0	1275	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 45	GCM maximum	-16.68%	2.2	234	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 75	GCM maximum	-31.16%	2.4	233	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes
Year 100	GCM maximum	-21.33%	2.7	315	less_optimal	Polar_Basin_Divergent	same_as_now	decrease	Yes

Table 3 continued.

	BBN node name	J1	B1	R1	J	R4	T1	E	T	T2
	Variable name	Tourism	Bear-human interactions	Oil & gas activity	Shipping	Hydrocarbons / oil spill	Contaminants	Intentional takes	Parasites & disease	Predation
	Unit of measure	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	increased same_as_now decreased	increased same_as_now decreased	increase no_change decrease	increased same_as_now	increased_occurrence same_as_now decreased_occurrence	elevated same_as_now reduced	increased same_as_now decreased	influential not	influential not
Time period	**Basis**									
					Polar Basin Divergent Ecoregion					
Year -10	Satellite data	decreased	decreased	decrease	same_as_now	same_as_now	reduced	decreased	not	not
Year 0	Satellite data	same_as_now	same_as_now	no_change	same_as_now	same_as_now	same_as_now	same_as_now	not	not
Year 45	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	GCM minimum	decreased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM minimum	decreased	increased	decrease	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	Ensemble mean	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	Ensemble mean	same_as_now	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	Ensemble mean	decreased	increased	decrease	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	GCM maximum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	GCM maximum	same_as_now	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM maximum	same_as_now	increased	decrease	increased	increased_occurrence	elevated	decreased	influential	influential

Table 3 continued.

Time Period	Basis	B	C	N	S1	M	R3	R2	F
	BBN node name	B	C	N	S1	M	R3	R2	F
	Variable name	Foraging habitat quantity change	Foraging habitat absence change	Shelf distance change	Foraging habitat character	Geographic area	Alternative prey availability	Relative ringed seal availability	Alternative regions available
	Unit of measure	% change from "now"	# of Months Different than now	km	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	any value < or = +20%	any value > or = -1	any value > or = -200	more_optimal same_as_now less_optimal	Polar_Basin_Divergent Polar_Basin_Convergent Archipelago Seasonal_Ice	increase same_as_now decrease	increase same_as_now decrease	Yes No
					Polar Basin Convergent Ecoregion				
Year -10	Satellite data	4.34%	-0.5	-41	same_as_now	Polar_Basin_Convergent	same_as_now	same_as_now	No
Year 0	Satellite data	0.00%	0.0	0	same_as_now	Polar_Basin_Convergent	same_as_now	same_as_now	No
Year 45	GCM minimum	-1.77%	0.9	831	same_as_now	Polar_Basin_Convergent	increase	same_as_now	No
Year 75	GCM minimum	-23.19%	1.9	1542	less_optimal	Polar_Basin_Convergent	decrease	decrease	No
Year 100	GCM minimum	-30.33%	2.5	1478	less_optimal	Polar_Basin_Convergent	decrease	decrease	No
Year 45	Ensemble mean	-13.85%	2.0	464	same_as_now	Polar_Basin_Convergent	increase	increase	No
Year 75	Ensemble mean	-22.65%	3.0	847	less_optimal	Polar_Basin_Convergent	decrease	same_as_now	No
Year 100	Ensemble mean	-25.02%	3.3	795	less_optimal	Polar_Basin_Convergent	decrease	decrease	No
Year 45	GCM maximum	-24.28%	2.9	334	same_as_now	Polar_Basin_Convergent	increase	increase	No
Year 75	GCM maximum	-30.23%	3.5	434	less_optimal	Polar_Basin_Convergent	increase	increase	No
Year 100	GCM maximum	-31.20%	3.7	510	less_optimal	Polar_Basin_Convergent	decrease	same_as_now	No

Table 3 continued.

	BBN node name	J1	B1	R1	J	R4	T1	E	T	T2
	Variable name	Tourism	Bear-human interactions	Oil & gas activity	Shipping	Hydrocarbons / oil spill	Contaminants	Intentional takes	Parasites & disease	Predation
	Unit of measure	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state	discrete state
	Allowable values	increased same_as_now decreased	increased same_as_now decreased	increase no_change decrease	increased same_as_now	increased_occurrence same_as_now decreased_occurrence	elevated same_as_now reduced	increased same_as_now decreased	influential not	influential not
Time period	**Basis**									
Polar Basin Convergent Ecoregion										
Year -10	Satellite data	decreased	decreased	decrease	same_as_now	same_as_now	reduced	same_as_now	not	not
Year 0	Satellite data	same_as_now	same_as_now	no_change	same_as_now	same_as_now	same_as_now	same_as_now	not	not
Year 45	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM minimum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	Ensemble mean	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	Ensemble mean	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	Ensemble mean	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 45	GCM maximum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 75	GCM maximum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential
Year 100	GCM maximum	increased	increased	increase	increased	increased_occurrence	elevated	decreased	influential	influential

Table 4. Amount, percent change, and summary of change in polar bear habitat forecasted by the deterministic polar bear carrying capacity model.

x = not calculated or data not available.

		Habitat amount (km^2-months x 1000)			% change in habitat from year 0		Change in Total Habitat from Year 0		
Time Period	Data basis	Total habitat	RSF habitat	Non-RSF habitat	RSF habitat	Total habitat	Direction[1]	Magnitude[2]	Summary
Seasonal Ice Ecoregion									
Year -10	Satellite data	16,258.70	x	x	x	17%	Expanding or stable	Moderate	Expanding moderate
Year 0	Satellite data	13,879.60	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 0	GCM minimum	11,217.33	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM minimum	10,054.93	x	x	x	-10%	Contracting	Slow to none	Contracting slow
Year 75	GCM minimum	7,640.68	x	x	x	-32%	Contracting	Fast	Contracting fast
Year 100	GCM minimum	7,615.55	x	x	x	-32%	Contracting	Fast	Contracting fast
Year 0	Ensemble mean	16,340.56	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	Ensemble mean	13,952.36	x	x	x	-15%	Contracting	Slow to none	Contracting slow
Year 75	Ensemble mean	12,132.32	x	x	x	-26%	Contracting	Moderate	Contracting moderate
Year 100	Ensemble mean	11,793.25	x	x	x	-28%	Contracting	Moderate	Contracting moderate
Year 0	GCM maximum	20,178.76	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM maximum	18,823.83	x	x	x	-7%	Contracting	Slow to none	Contracting slow
Year 75	GCM maximum	15,909.29	x	x	x	-21%	Contracting	Moderate	Contracting moderate
Year 100	GCM maximum	15,802.26	x	x	x	-22%	Contracting	Moderate	Contracting moderate

[1] Direction was categorized into "contracting" if $CH_{t,G} < 0$ or "expanding or stable" if $CH_{t,G} \geq 0$.

[2] Magnitude was categorized into "fast" if $|CH_{t,G}| > 30.0$, "moderate" if $15.0 < |CH_{t,G}| \leq 30.0$, and "slow or none" if $|CH_{t,G}| < 15.0$.

Table 4 continued.

		Habitat amount (km^2-months x 1000)			% change in habitat from year 0		Change in Total Habitat from Year 0		
Time Period	Data basis	Total habitat	RSF habitat	Non-RSF habitat	RSF habitat	Total habitat	Direction	Magnitude	Summary
				Archipelago Ecoregion					
Year -10	Satellite data	6,903.69	x	x	x	3%	Expanding or stable	Slow to none	Stable
Year 0	Satellite data	6,689.17	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 0	GCM minimum	5,784.55	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM minimum	4,986.82	x	x	x	-14%	Contracting	Slow to none	Contracting slow
Year 75	GCM minimum	4,586.46	x	x	x	-21%	Contracting	Moderate	Contracting moderate
Year 100	GCM minimum	4,378.68	x	x	x	-24%	Contracting	Moderate	Contracting moderate
Year 0	Ensemble mean	7,158.84	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	Ensemble mean	6,305.10	x	x	x	-12%	Contracting	Slow to none	Contracting slow
Year 75	Ensemble mean	5,722.95	x	x	x	-20%	Contracting	Moderate	Contracting moderate
Year 100	Ensemble mean	5,572.14	x	x	x	-22%	Contracting	Moderate	Contracting moderate
Year 0	GCM maximum	8,298.05	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM maximum	8,013.84	x	x	x	-3%	Contracting	Slow to none	Contracting slow
Year 75	GCM maximum	6,802.87	x	x	x	-18%	Contracting	Moderate	Contracting moderate
Year 100	GCM maximum	6,568.13	x	x	x	-21%	Contracting	Moderate	Contracting moderate
				Polar Basin Divergent Ecoregion					
Year -10	Satellite data	35,066.08	12,253.30	22,812.78	5%	4%	Expanding or stable	Slow to none	Stable
Year 0	Satellite data	33,563.40	11,633.44	21,929.96	0%	0%	Expanding or stable	Slow to none	Stable
Year 0	GCM minimum	31,741.23	11,032.20	20,709.03	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM minimum	21,207.61	7,043.79	14,163.82	-36%	-33%	Contracting	Fast	Contracting fast
Year 75	GCM minimum	18,503.41	6,107.96	12,395.45	-45%	-42%	Contracting	Fast	Contracting fast
Year 100	GCM minimum	16,871.39	5,575.40	11,295.99	-49%	-47%	Contracting	Fast	Contracting fast
Year 0	Ensemble mean	38,753.63	12,560.31	26,193.32	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	Ensemble mean	30,582.79	10,135.02	20,447.77	-19%	-21%	Contracting	Moderate	Contracting moderate
Year 75	Ensemble mean	26,399.58	8,580.94	17,818.64	-32%	-32%	Contracting	Fast	Contracting fast
Year 100	Ensemble mean	24,992.14	8,067.62	16,924.52	-36%	-36%	Contracting	Fast	Contracting fast
Year 0	GCM maximum	45,672.05	14,591.97	31,080.08	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM maximum	36,092.83	12,158.61	23,934.22	-17%	-21%	Contracting	Moderate	Contracting moderate
Year 75	GCM maximum	33,664.81	10,045.76	23,619.05	-31%	-26%	Contracting	Moderate	Contracting moderate
Year 100	GCM maximum	34,293.06	11,479.88	22,813.18	-21%	-25%	Contracting	Moderate	Contracting moderate

Table 4 continued.

		Habitat amount (km²-months x 1000)			% change in habitat from year 0		Change in Total Habitat from Year 0		
Time Period	Data basis	Total habitat	RSF habitat	Non-RSF habitat	RSF habitat	Total habitat	Direction	Magnitude	Summary
Polar Basin Convergent Ecoregion									
Year -10	Satellite data	6,063.56	5,440.34	623.22	4%	4%	Expanding or stable	Slow to none	Stable
Year 0	Satellite data	5,823.36	5,214.13	609.23	0%	0%	Expanding or stable	Slow to none	Stable
Year 0	GCM minimum	4,945.44	4,136.50	808.94	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM minimum	4,424.39	4,063.23	361.16	-2%	-11%	Contracting	Slow to none	Contracting slow
Year 75	GCM minimum	4,042.15	3,177.04	865.11	-23%	-18%	Contracting	Moderate	Contracting moderate
Year 100	GCM minimum	3,539.31	2,881.99	657.32	-30%	-28%	Contracting	Moderate	Contracting moderate
Year 0	Ensemble mean	6,305.23	5,158.01	1,147.22	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	Ensemble mean	5,334.67	4,443.39	891.28	-14%	-15%	Contracting	Moderate	Contracting moderate
Year 75	Ensemble mean	4,739.31	3,989.57	749.74	-23%	-25%	Contracting	Moderate	Contracting moderate
Year 100	Ensemble mean	4,566.56	3,867.34	699.22	-25%	-28%	Contracting	Moderate	Contracting moderate
Year 0	GCM maximum	7,068.41	6,023.03	1,045.38	0%	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM maximum	6,115.28	4,560.71	1,554.57	-24%	-13%	Contracting	Slow to none	Contracting slow
Year 75	GCM maximum	5,538.43	4,202.23	1,336.20	-30%	-22%	Contracting	Moderate	Contracting moderate
Year 100	GCM maximum	5,625.88	4,143.95	1,481.93	-31%	-20%	Contracting	Moderate	Contracting moderate
Global (all ecoregions combined)									
Year -10	Satellite data	64,292.03	x	x	x	7%	Expanding or stable	Slow to none	Stable
Year 0	Satellite data	59,955.53	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 0	GCM minimum	53,688.55	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM minimum	40,673.75	x	x	x	-24%	Contracting	Moderate	Contracting moderate
Year 75	GCM minimum	34,772.70	x	x	x	-35%	Contracting	Fast	Contracting fast
Year 100	GCM minimum	32,404.93	x	x	x	-40%	Contracting	Fast	Contracting fast
Year 0	Ensemble mean	68,558.26	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	Ensemble mean	56,174.92	x	x	x	-18%	Contracting	Moderate	Contracting moderate
Year 75	Ensemble mean	48,994.16	x	x	x	-29%	Contracting	Moderate	Contracting moderate
Year 100	Ensemble mean	46,924.09	x	x	x	-32%	Contracting	Fast	Contracting fast
Year 0	GCM maximum	81,217.27	x	x	x	0%	Expanding or stable	Slow to none	Stable
Year 45	GCM maximum	69,045.78	x	x	x	-15%	Contracting	Slow to none	Contracting slow
Year 75	GCM maximum	61,915.40	x	x	x	-24%	Contracting	Moderate	Contracting moderate
Year 100	GCM maximum	62,289.33	x	x	x	-23%	Contracting	Moderate	Contracting moderate

Table 5. Numbers and densities of polar bears by ecoregion, based on habitat amount at year 0 (Table 4).

x = not calculated or data not available.

Ecoregion	Numbers of polar bears	Polar bear density (km^2-months x 1000 per bear)		
		Crude density, based on non-RSF habitat	Ecological density, based on RSF habitat	Total density, based on total habitat
Seasonal Ice	7800	x	x	1.779
Archipelago	5000	x	x	1.338
Polar Basin Divergent	9500	7.695	1.749	x
Polar Basin Convergent	2200	0.923	3.386	x

Table 6. Polar bear carrying capacity forecast for each ecoregion, time period, and modeling basis, by the deterministic polar bear carrying capacity model.

x = not calculated or data not available.

		Carrying capacity (K) expressed as polar bear population size (no. bears), not normalized to year 0				% change in carrying capacity from year 0				Carrying capacity normalized to year 0		Change in total carrying capacity from year 0		
Time Period	Data basis	Based on all habitat	Based on RSF habitat	Based on non-RSF habitat	TOTAL	Based on all habitat	Based on RSF habitat	Based on non-RSF habitat	TOTAL	Based on RSF habitat	TOTAL	Direction[4]	Magnitude[5]	Summary
Seasonal Ice Ecoregion														
Year -10	Satellite data	9,137	x	x	9,137	17%	x	x	17%	x	9,137	stab_incr	moderate	Increasing moderate
Year 0	Satellite data	7,800	x	x	7,800	0%	x	x	0%	x	7,800	stab_incr	Low to none	Stable
Year 0	GCM minimum	6,304	x	x	6,304	0%	x	x	0%	x	7,800	stab_incr	Low to none	Stable
Year 45	GCM minimum	5,651	x	x	5,651	-10%	x	x	-10%	x	6,992	Decreasing	Low to none	Decreasing low
Year 75	GCM minimum	4,294	x	x	4,294	-32%	x	x	-32%	x	5,313	Decreasing	high	Decreasing high
Year 100	GCM minimum	4,280	x	x	4,280	-32%	x	x	-32%	x	5,295	Decreasing	high	Decreasing high
Year 0	Ensemble mean	9,183	x	x	9,183	0%	x	x	0%	x	7,800	stab_incr	Low to none	Stable
Year 45	Ensemble mean	7,841	x	x	7,841	-15%	x	x	-15%	x	6,660	Decreasing	Low to none	Decreasing low
Year 75	Ensemble mean	6,818	x	x	6,818	-26%	x	x	-26%	x	5,791	Decreasing	moderate	Decreasing moderate
Year 100	Ensemble mean	6,628	x	x	6,628	-28%	x	x	-28%	x	5,629	Decreasing	moderate	Decreasing moderate
Year 0	GCM maximum	11,340	x	x	11,340	0%	x	x	0%	x	7,800	stab_incr	Low to none	Stable
Year 45	GCM maximum	10,579	x	x	10,579	-7%	x	x	-7%	x	7,276	Decreasing	Low to none	Decreasing low
Year 75	GCM maximum	8,941	x	x	8,941	-21%	x	x	-21%	x	6,150	Decreasing	moderate	Decreasing moderate
Year 100	GCM maximum	8,880	x	x	8,880	-22%	x	x	-22%	x	6,108	Decreasing	moderate	Decreasing moderate

[4] Direction was categorized into "decreasing" if $CK_{t,G} < 0$ or "stable or increasing" if $CK_{t,G} \geq 0$.

[5] Magnitude was categorized into "high" if $|CK_{t,G}| > 30.0$, "moderate" if $15.0 < |CK_{t,G}| \leq 30.0$, and "low to none" if $|CK_{t,G}| < 15.0$.

Table 6 continued.

		Carrying capacity (K) expressed as polar bear population size (no. bears), not normalized to year 0				% change in carrying capacity from year 0				Carrying capacity normalized to year 0		Change in total carrying capacity from year 0		
Time Period	**Data basis**	**Based on all habitat**	**Based on RSF habitat**	**Based on non-RSF habitat**	**TOTAL**	**Based on all habitat**	**Based on RSF habitat**	**Based on non-RSF habitat**	**TOTAL**	**Based on RSF habitat**	**TOTAL**	**Direction**	**Magnitude**	**Summary**
Archipelago Ecoregion														
Year -10	Satellite data	5,160	x	x	5,160	3%	x	x	3%	x	5,160	stab_incr	Low to none	Stable
Year 0	Satellite data	5,000	x	x	5,000	0%	x	x	0%	x	5,000	stab_incr	Low to none	Stable
Year 0	GCM minimum	4,324	x	x	4,324	0%	x	x	0%	x	5,000	stab_incr	Low to none	Stable
Year 45	GCM minimum	3,728	x	x	3,728	-14%	x	x	-14%	x	4,310	Decreasing	Low to none	Decreasing low
Year 75	GCM minimum	3,428	x	x	3,428	-21%	x	x	-21%	x	3,964	Decreasing	Moderate	Decreasing moderate
Year 100	GCM minimum	3,273	x	x	3,273	-24%	x	x	-24%	x	3,785	Decreasing	Moderate	Decreasing moderate
Year 0	Ensemble mean	5,351	x	x	5,351	0%	x	x	0%	x	5,000	Stable-Incr	Low to none	Stable
Year 45	Ensemble mean	4,713	x	x	4,713	-12%	x	x	-12%	x	4,404	Decreasing	Low to none	Decreasing low
Year 75	Ensemble mean	4,278	x	x	4,278	-20%	x	x	-20%	x	3,997	Decreasing	Moderate	Decreasing moderate
Year 100	Ensemble mean	4,165	x	x	4,165	-22%	x	x	-22%	x	3,892	Decreasing	Moderate	Decreasing moderate
Year 0	GCM maximum	6,203	x	x	6,203	0%	x	x	0%	x	5,000	Stable-Incr	Low to none	Stable
Year 45	GCM maximum	5,990	x	x	5,990	-3%	x	x	-3%	x	4,829	Decreasing	Low to none	Decreasing low
Year 75	GCM maximum	5,085	x	x	5,085	-18%	x	x	-18%	x	4,099	Decreasing	Moderate	Decreasing moderate
Year 100	GCM maximum	4,910	x	x	4,910	-21%	x	x	-21%	x	3,958	Decreasing	Moderate	Decreasing moderate
Polar Basin Divergent Ecoregion														
Year -10	Satellite data	x	7,004	2,965	9,969	x	5%	4%	5%	7,004	9,969	Stable-Incr	Low to none	Stable
Year 0	Satellite data	x	6,650	2,850	9,500	x	0%	0%	0%	6,650	9,500	Stable-Incr	Low to none	Stable
Year 0	GCM minimum	x	6,306	2,691	8,998	x	0%	0%	0%	6,650	9,500	Stable-Incr	Low to none	Stable
Year 45	GCM minimum	x	4,026	1,841	5,867	x	-36%	-32%	-35%	4,246	6,195	Decreasing	High	Decreasing high
Year 75	GCM minimum	x	3,491	1,611	5,102	x	-45%	-40%	-43%	3,682	5,387	Decreasing	High	Decreasing high
Year 100	GCM minimum	x	3,187	1,468	4,655	x	-49%	-45%	-48%	3,361	4,915	Decreasing	High	Decreasing high
Year 0	Ensemble mean	x	7,180	3,404	10,584	x	0%	0%	0%	6,650	9,500	Stable-Incr	Low to none	Stable
Year 45	Ensemble mean	x	5,793	2,657	8,451	x	-19%	-22%	-20%	5,366	7,585	Decreasing	Moderate	Decreasing moderate
Year 75	Ensemble mean	x	4,905	2,316	7,221	x	-32%	-32%	-32%	4,543	6,481	Decreasing	High	Decreasing high
Year 100	Ensemble mean	x	4,612	2,199	6,811	x	-36%	-35%	-36%	4,271	6,114	Decreasing	High	Decreasing high
Year 0	GCM maximum	x	8,341	4,039	12,380	x	0%	0%	0%	6,650	9,500	Stable-Incr	Low to none	Stable
Year 45	GCM maximum	x	6,950	3,110	10,061	x	-17%	-23%	-19%	5,541	7,720	Decreasing	Moderate	Decreasing moderate
Year 75	GCM maximum	x	5,742	3,070	8,812	x	-31%	-24%	-29%	4,578	6,762	Decreasing	Moderate	Decreasing moderate
Year 100	GCM maximum	x	6,562	2,965	9,527	x	-21%	-27%	-23%	5,232	7,311	Decreasing	Moderate	Decreasing moderate

Table 6 continued.

		Carrying capacity (K) expressed as polar bear population size (no. bears), not normalized to year 0				% change in carrying capacity from year 0				Carrying capacity normalized to year 0		Change in total carrying capacity from year 0		
Time Period	Data basis	Based on all habitat	Based on RSF habitat	Based on non-RSF habitat	TOTAL	Based on all habitat	Based on RSF habitat	Based on non-RSF habitat	TOTAL	Based on RSF habitat	TOTAL	Direction	Magnitude	Summary
Polar Basin Convergent Ecoregion														
Year -10	Satellite data	x	1,607	675	2,282	x	4%	2%	4%	1,607	2,282	Stable-Incr	Low to none	Stable
Year 0	Satellite data	x	1,540	660	2,200	x	0%	0%	0%	1,540	2,200	Stable-Incr	Low to none	Stable
Year 0	GCM minimum	x	1,222	876	2,098	x	0%	0%	0%	1,540	2,200	Stable-Incr	Low to none	Stable
Year 45	GCM minimum	x	1,200	391	1,591	x	-2%	-55%	-24%	1,513	1,669	Decreasing	Moderate	Decreasing moderate
Year 75	GCM minimum	x	938	937	1,876	x	-23%	7%	-11%	1,183	1,967	Decreasing	Low to none	Decreasing low
Year 100	GCM minimum	x	851	712	1,563	x	-30%	-19%	-25%	1,073	1,639	Decreasing	Moderate	Decreasing moderate
Year 0	Ensemble mean	x	1,523	1,243	2,766	x	0%	0%	0%	1,540	2,200	Stable-Incr	Low to none	Stable
Year 45	Ensemble mean	x	1,312	966	2,278	x	-14%	-22%	-18%	1,327	1,812	Decreasing	Moderate	Decreasing moderate
Year 75	Ensemble mean	x	1,178	812	1,991	x	-23%	-35%	-28%	1,191	1,583	Decreasing	Moderate	Decreasing moderate
Year 100	Ensemble mean	x	1,142	757	1,900	x	-25%	-39%	-31%	1,155	1,511	Decreasing	High	Decreasing high
Year 0	GCM maximum	x	1,779	1,132	2,911	x	0%	0%	0%	1,540	2,200	Stable-Incr	Low to none	Stable
Year 45	GCM maximum	x	1,347	1,684	3,031	x	-24%	49%	4%	1,166	2,290	Stable-Incr	Low to none	Stable
Year 75	GCM maximum	x	1,241	1,448	2,689	x	-30%	28%	-8%	1,074	2,032	Decreasing	Low to none	Decreasing low
Year 100	GCM maximum	x	1,224	1,605	2,829	x	-31%	42%	-3%	1,060	2,138	Decreasing	Low to none	Decreasing low
Global (all ecoregions combined)														
Year -10	Satellite data	x	x	x	26,548	x	x	x	8%	x	26,548	Stable-Incr	Low to none	Stable
Year 0	Satellite data	x	x	x	24,500	x	x	x	0%	x	24,500	Stable-Incr	Low to none	Stable
Year 0	GCM minimum	x	x	x	21,723	x	x	x	0%	x	24,500	Stable-Incr	Low to none	Stable
Year 45	GCM minimum	x	x	x	16,837	x	x	x	-22%	x	18,989	Decreasing	Moderate	Decreasing moderate
Year 75	GCM minimum	x	x	x	14,700	x	x	x	-32%	x	16,579	Decreasing	High	Decreasing high
Year 100	GCM minimum	x	x	x	13,771	x	x	x	-37%	x	15,531	Decreasing	High	Decreasing high
Year 0	Ensemble mean	x	x	x	27,884	x	x	x	0%	x	24,500	Stable-Incr	Low to none	Stable
Year 45	Ensemble mean	x	x	x	23,283	x	x	x	-17%	x	20,457	Decreasing	Moderate	Decreasing moderate
Year 75	Ensemble mean	x	x	x	20,307	x	x	x	-27%	x	17,843	Decreasing	Moderate	Decreasing moderate
Year 100	Ensemble mean	x	x	x	19,503	x	x	x	-30%	x	17,136	Decreasing	High	Decreasing high
Year 0	GCM maximum	x	x	x	32,834	x	x	x	0%	x	24,500	Stable-Incr	Low to none	Stable
Year 45	GCM maximum	x	x	x	29,661	x	x	x	-10%	x	22,132	Decreasing	Low to none	Decreasing low
Year 75	GCM maximum	x	x	x	25,526	x	x	x	-22%	x	19,047	Decreasing	Moderate	Decreasing moderate
Year 100	GCM maximum	x	x	x	26,146	x	x	x	-20%	x	19,510	Decreasing	Moderate	Decreasing moderate

Table 7. Overall summary of change in total polar bear carrying capacity from present levels (based on applying results of carrying capacity calculations in Table 6 to the rule set in Table 2).

Time Period	Data basis	Overall Summary
Seasonal Ice Ecoregion		
Year -10	Satellite data	enhanced
Year 0	Satellite data	maintained
Year 0	GCM minimum	maintained
Year 45	GCM minimum	decreased
Year 75	GCM minimum	
Year 100	GCM minimum	
Year 0	Ensemble mean	maintained
Year 45	Ensemble mean	decreased
Year 75	Ensemble mean	decreased
Year 100	Ensemble mean	decreased
Year 0	GCM maximum	maintained
Year 45	GCM maximum	decreased
Year 75	GCM maximum	decreased
Year 100	GCM maximum	decreased
Archipelago Ecoregion		
Year -10	Satellite data	maintained
Year 0	Satellite data	maintained
Year 0	GCM minimum	maintained
Year 45	GCM minimum	decreased
Year 75	GCM minimum	decreased
Year 100	GCM minimum	decreased
Year 0	Ensemble mean	maintained
Year 45	Ensemble mean	decreased
Year 75	Ensemble mean	decreased
Year 100	Ensemble mean	decreased
Year 0	GCM maximum	maintained
Year 45	GCM maximum	decreased
Year 75	GCM maximum	decreased
Year 100	GCM maximum	decreased
Polar Basin Divergent Ecoregion		
Year -10	Satellite data	maintained
Year 0	Satellite data	maintained
Year 0	GCM minimum	maintained
Year 45	GCM minimum	
Year 75	GCM minimum	
Year 100	GCM minimum	
Year 0	Ensemble mean	maintained
Year 45	Ensemble mean	decreased
Year 75	Ensemble mean	

Time Period	Data basis	Overall Summary
Year 100	Ensemble mean	
Year 0	GCM maximum	maintained
Year 45	GCM maximum	decreased
Year 75	GCM maximum	decreased
Year 100	GCM maximum	decreased
Polar Basin Convergent Ecoregion		
Year -10	Satellite data	maintained
Year 0	Satellite data	maintained
Year 0	GCM minimum	maintained
Year 45	GCM minimum	decreased
Year 75	GCM minimum	decreased
Year 100	GCM minimum	decreased
Year 0	Ensemble mean	maintained
Year 45	Ensemble mean	decreased
Year 75	Ensemble mean	decreased
Year 100	Ensemble mean	
Year 0	GCM maximum	maintained
Year 45	GCM maximum	decreased
Year 75	GCM maximum	decreased
Year 100	GCM maximum	decreased
Global (all ecoregions combined)		
Year -10	Satellite data	maintained
Year 0	Satellite data	maintained
Year 0	GCM minimum	maintained
Year 45	GCM minimum	decreased
Year 75	GCM minimum	
Year 100	GCM minimum	
Year 0	Ensemble mean	maintained
Year 45	Ensemble mean	decreased
Year 75	Ensemble mean	decreased
Year 100	Ensemble mean	
Year 0	GCM maximum	maintained
Year 45	GCM maximum	decreased
Year 75	GCM maximum	decreased
Year 100	GCM maximum	decreased

Table 8. Results of the Bayesian network population stressor model, showing the most probable outcome state, and probabilities of each state (larger, same as now, smaller, rare, and extinct), for overall population outcome (node D1; see Figure 5).

		Node D1: Overall Population Outcome					
Time period	**Basis**	**Most probable outcome**	**P(D1= larger)**	**P(D1= same as now)**	**P(D1= smaller)**	**P(D1= rare)**	**P(D1= extinct)**
		Seasonal Ice Ecoregion					
Year -10	Satellite data	larger	93.92%	5.75%	0.30%	0.02%	0.00%
Year 0	Satellite data	same_as_now	21.85%	43.72%	18.98%	8.37%	7.07%
Year 45	GCM minimum	extinct	0.05%	0.61%	9.79%	12.36%	77.19%
Year 75	GCM minimum	extinct	0.00%	0.09%	3.48%	8.28%	88.15%
Year 100	GCM minimum	extinct	0.00%	0.09%	3.48%	8.28%	88.15%
Year 45	Ensemble mean	extinct	0.05%	0.61%	9.79%	12.36%	77.19%
Year 75	Ensemble mean	extinct	0.00%	0.09%	3.48%	8.28%	88.15%
Year 100	Ensemble mean	extinct	0.00%	0.09%	3.48%	8.28%	88.15%
Year 45	GCM maximum	extinct	0.24%	2.20%	24.37%	19.35%	53.85%
Year 75	GCM maximum	extinct	0.01%	0.18%	5.17%	9.52%	85.11%
Year 100	GCM maximum	extinct	0.01%	0.18%	5.17%	9.52%	85.11%
		Archipelago Ecoregion					
Year -10	Satellite data	same_as_now	22.51%	34.73%	31.48%	8.72%	2.56%
Year 0	Satellite data	larger	69.48%	29.26%	1.06%	0.19%	0.00%
Year 45	GCM minimum	smaller	4.57%	12.93%	51.34%	20.60%	10.56%
Year 75	GCM minimum	extinct	0.89%	3.16%	32.07%	19.34%	44.54%
Year 100	GCM minimum	extinct	1.38%	4.65%	33.38%	19.51%	41.07%
Year 45	Ensemble mean	smaller	4.57%	12.93%	51.34%	20.60%	10.56%
Year 75	Ensemble mean	extinct	1.05%	3.34%	32.25%	26.07%	37.30%
Year 100	Ensemble mean	extinct	1.38%	4.65%	33.38%	19.51%	41.07%
Year 45	GCM maximum	smaller	5.83%	15.93%	52.35%	18.01%	7.88%
Year 75	GCM maximum	smaller	4.42%	12.40%	49.36%	22.96%	10.85%
Year 100	GCM maximum	extinct	1.38%	4.65%	33.38%	19.51%	41.07%

Table 8 continued.

Time period	Basis	Node D1: Overall Population Outcome					
		Most probable outcome	P(D1= larger)	P(D1= same as now)	P(D1= smaller)	P(D1= rare)	P(D1= extinct)
Polar Basin Divergent Ecoregion							
Year -10	Satellite data	larger	99.78%	0.22%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	24.16%	56.60%	13.36%	4.73%	1.14%
Year 45	GCM minimum	extinct	0.00%	0.00%	2.86%	10.58%	86.55%
Year 75	GCM minimum	extinct	0.00%	0.00%	3.07%	10.91%	86.02%
Year 100	GCM minimum	extinct	0.00%	0.00%	3.88%	12.23%	83.89%
Year 45	Ensemble mean	extinct	0.00%	0.18%	6.16%	13.34%	80.33%
Year 75	Ensemble mean	extinct	0.00%	0.00%	2.86%	10.58%	86.55%
Year 100	Ensemble mean	extinct	0.00%	0.00%	3.88%	12.23%	83.89%
Year 45	GCM maximum	extinct	0.00%	0.18%	6.16%	13.34%	80.33%
Year 75	GCM maximum	extinct	0.00%	0.07%	4.46%	12.00%	83.47%
Year 100	GCM maximum	extinct	0.00%	0.09%	5.73%	13.84%	80.33%
Polar Basin Convergent Ecoregion							
Year -10	Satellite data	larger	98.39%	1.61%	0.00%	0.00%	0.00%
Year 0	Satellite data	larger	71.69%	27.49%	0.63%	0.19%	0.00%
Year 45	GCM minimum	extinct	0.26%	2.30%	27.98%	31.59%	37.87%
Year 75	GCM minimum	extinct	0.00%	0.39%	9.68%	13.24%	76.70%
Year 100	GCM minimum	extinct	0.00%	0.39%	9.68%	13.24%	76.70%
Year 45	Ensemble mean	extinct	0.48%	2.72%	29.27%	32.46%	35.06%
Year 75	Ensemble mean	extinct	0.00%	0.27%	8.40%	15.10%	76.23%
Year 100	Ensemble mean	extinct	0.02%	0.44%	9.49%	12.75%	77.30%
Year 45	GCM maximum	extinct	0.14%	1.24%	21.15%	30.71%	46.77%
Year 75	GCM maximum	extinct	0.02%	0.46%	12.64%	24.46%	62.41%
Year 100	GCM maximum	extinct	0.02%	0.44%	10.51%	16.52%	72.52%

Table 9 continued.

Time period	Basis	Node C3: Distribution Response: Most probable outcome	P(C3= same as now)	P(C3= reduced but resident)	P(C3= transient visitors)	P(C3= extirpated)	Node C4: Numerical Response: Most probable outcome	P(C4= increased density)	P(C4= same as now)	P(C4= reduced density)	P(C4= rare)	P(C4= absent)
Polar Basin Divergent Ecoregion												
Year -10	Satellite data	same_as_now	100.00%	0.00%	0.00%	0.00%	increased_density	99.78%	0.22%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	85.66%	8.37%	4.82%	1.14%	same_as_now	24.16%	59.71%	16.12%	0.00%	0.00%
Year 45	GCM minimum	extirpated	0.00%	0.00%	18.00%	82.00%	reduced_density	0.00%	0.00%	53.00%	31.00%	16.00%
Year 75	GCM minimum	extirpated	0.00%	0.30%	18.27%	81.43%	reduced_density	0.00%	0.00%	53.33%	30.91%	15.76%
Year 100	GCM minimum	extirpated	0.00%	1.50%	19.35%	79.15%	reduced_density	0.00%	0.00%	54.65%	30.55%	14.80%
Year 45	Ensemble mean	extirpated	2.14%	2.99%	19.98%	74.89%	reduced_density	0.00%	0.56%	53.90%	30.04%	15.51%
Year 75	Ensemble mean	extirpated	0.00%	0.00%	18.00%	82.00%	reduced_density	0.00%	0.00%	53.00%	31.00%	16.00%
Year 100	Ensemble mean	extirpated	0.00%	1.50%	19.35%	79.15%	reduced_density	0.00%	0.00%	54.65%	30.55%	14.80%
Year 45	GCM maximum	extirpated	2.14%	2.99%	19.98%	74.89%	reduced_density	0.00%	0.56%	53.90%	30.04%	15.51%
Year 75	GCM maximum	extirpated	1.02%	1.50%	19.04%	78.44%	reduced_density	0.00%	0.26%	53.42%	30.55%	15.77%
Year 100	GCM maximum	extirpated	1.11%	3.30%	20.44%	75.15%	reduced_density	0.00%	0.27%	55.35%	30.02%	14.35%
Polar Basin Convergent Ecoregion												
Year -10	Satellite data	same_as_now	100.00%	0.00%	0.00%	0.00%	increased_density	98.39%	1.61%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	99.40%	0.43%	0.18%	0.00%	increased_density	71.69%	27.65%	0.66%	0.00%	0.00%
Year 45	GCM minimum	transient_visitors	17.71%	14.07%	40.63%	27.59%	reduced_density	0.31%	5.23%	60.81%	22.19%	11.45%
Year 75	GCM minimum	extirpated	4.72%	8.32%	15.48%	71.48%	reduced_density	0.00%	1.27%	55.04%	28.82%	14.87%
Year 100	GCM minimum	extirpated	4.72%	8.32%	15.48%	71.48%	reduced_density	0.00%	1.27%	55.04%	28.82%	14.87%
Year 45	Ensemble mean	transient_visitors	18.56%	13.79%	42.66%	24.99%	reduced_density	0.69%	6.01%	61.31%	21.10%	10.89%
Year 75	Ensemble mean	extirpated	3.53%	5.29%	20.93%	70.24%	reduced_density	0.00%	0.95%	54.53%	29.37%	15.16%
Year 100	Ensemble mean	extirpated	4.55%	8.08%	15.05%	72.32%	reduced_density	0.04%	1.34%	55.08%	28.72%	14.82%
Year 45	GCM maximum	transient_visitors	11.44%	10.51%	41.88%	36.17%	reduced_density	0.23%	3.51%	58.19%	25.11%	12.96%
Year 75	GCM maximum	extirpated	5.32%	5.39%	36.12%	53.17%	reduced_density	0.05%	1.58%	55.44%	28.31%	14.61%
Year 100	GCM maximum	extirpated	4.80%	7.22%	21.82%	66.16%	reduced_density	0.05%	1.42%	55.19%	28.59%	14.75%

Table 9. Results of the Bayesian network population stressor model, showing the most probable outcome states, and probabilities of each state, for the distribution response and numerical response outcomes (nodes C3, C4; see Figure 5).

		Node C3: Distribution Response					Node C4: Numerical Response					
Time period	Basis	Most probable outcome	P(C3= same as now)	P(C3= reduced but resident)	P(C3= transient visitors)	P(C3= extirpated)	Most probable outcome	P(C4= increased density)	P(C4= same as now)	P(C4= reduced density)	P(C4= rare)	P(C4= absent)
Seasonal Ice Ecoregion												
Year -10	Satellite data	same_as_now	99.79%	0.21%	0.00%	0.00%	increased_density	93.93%	5.83%	0.24%	0.00%	0.00%
Year 0	Satellite data	same_as_now	72.47%	11.59%	8.88%	7.07%	same_as_now	21.90%	47.20%	30.90%	0.00%	0.00%
Year 45	GCM minimum	extirpated	4.69%	8.13%	14.51%	72.68%	reduced_density	0.09%	1.40%	56.27%	28.38%	13.87%
Year 75	GCM minimum	extirpated	0.94%	1.66%	12.70%	84.70%	reduced_density	0.01%	0.27%	53.42%	30.54%	15.76%
Year 100	GCM minimum	extirpated	0.94%	1.66%	12.70%	84.70%	reduced_density	0.01%	0.27%	53.42%	30.54%	15.76%
Year 45	Ensemble mean	extirpated	4.69%	8.13%	14.51%	72.68%	reduced_density	0.09%	1.40%	56.27%	28.38%	13.87%
Year 75	Ensemble mean	extirpated	0.94%	1.66%	12.70%	84.70%	reduced_density	0.01%	0.27%	53.42%	30.54%	15.76%
Year 100	Ensemble mean	extirpated	0.94%	1.66%	12.70%	84.70%	reduced_density	0.01%	0.27%	53.42%	30.54%	15.76%
Year 45	GCM maximum	extirpated	14.83%	20.97%	16.84%	47.35%	reduced_density	0.35%	4.54%	60.26%	23.40%	11.44%
Year 75	GCM maximum	extirpated	1.96%	3.52%	13.30%	81.22%	reduced_density	0.02%	0.57%	53.88%	30.03%	15.50%
Year 100	GCM maximum	extirpated	1.96%	3.52%	13.30%	81.22%	reduced_density	0.02%	0.57%	53.88%	30.03%	15.50%
Archipelago Ecoregion												
Year -10	Satellite data	same_as_now	71.72%	18.29%	8.74%	1.25%	same_as_now	24.36%	41.18%	31.17%	2.19%	1.09%
Year 0	Satellite data	same_as_now	99.40%	0.43%	0.18%	0.00%	increased_density	69.49%	29.41%	1.11%	0.00%	0.00%
Year 45	GCM minimum	same_as_now	56.09%	16.39%	24.50%	3.03%	reduced_density	5.36%	15.63%	63.62%	8.32%	7.07%
Year 75	GCM minimum	extirpated	23.49%	25.05%	16.32%	35.14%	reduced_density	1.14%	4.99%	55.92%	21.22%	16.73%
Year 100	GCM minimum	extirpated	23.49%	25.05%	16.32%	35.14%	reduced_density	1.76%	7.92%	62.24%	18.53%	9.56%
Year 45	Ensemble mean	same_as_now	56.09%	16.39%	24.50%	3.03%	reduced_density	5.36%	15.63%	63.62%	8.32%	7.07%
Year 75	Ensemble mean	transient_visitors	24.66%	17.46%	32.64%	25.25%	reduced_density	1.34%	5.39%	56.47%	20.58%	16.23%
Year 100	Ensemble mean	extirpated	23.49%	25.05%	16.32%	35.14%	reduced_density	1.76%	7.92%	62.24%	18.53%	9.56%
Year 45	GCM maximum	same_as_now	61.02%	15.59%	21.31%	2.08%	reduced_density	6.81%	18.88%	62.63%	6.32%	5.37%
Year 75	GCM maximum	same_as_now	51.08%	16.90%	28.65%	3.37%	reduced_density	5.36%	15.63%	63.62%	8.32%	7.07%
Year 100	GCM maximum	extirpated	23.49%	25.05%	16.32%	35.14%	reduced_density	1.76%	7.92%	62.24%	18.53%	9.56%

Table 10. Results of the Bayesian network population stressor model, showing the most probable outcome states, and probabilities of each state, for habitat threats and director mortalities summary variables (nodes F2 and A1; see Fig. 5).

		Node F2: Factor A: Habitat Threats					Node A1: Factor B: Direct Mortalities			
Time period	Basis	Most probable outcome	P(F2= improve-ment)	P(F2= no effect)	P(F2= minor restriction)	P(F2= major restriction)	Most probable outcome	P(A1= fewer)	P(A1= same as now)	P(A1= more)
Seasonal Ice Ecoregion										
Year -10	Satellite data	improvement	94.60%	5.00%	0.40%	0.00%	fewer	100.00%	0.00%	0.00%
Year 0	Satellite data	no_effect	26.41%	36.84%	23.02%	13.72%	same_as_now	0.00%	100.00%	0.00%
Year 45	GCM minimum	major_restriction	0.08%	2.00%	16.64%	81.28%	same_as_now	0.00%	62.60%	37.40%
Year 75	GCM minimum	major_restriction	0.00%	0.00%	4.72%	95.28%	same_as_now	0.00%	60.00%	40.00%
Year 100	GCM minimum	major_restriction	0.00%	0.00%	4.72%	95.28%	same_as_now	0.00%	60.00%	40.00%
Year 45	Ensemble mean	major_restriction	0.08%	2.00%	16.64%	81.28%	same_as_now	0.00%	62.60%	37.40%
Year 75	Ensemble mean	major_restriction	0.00%	0.00%	4.72%	95.28%	same_as_now	0.00%	60.00%	40.00%
Year 100	Ensemble mean	major_restriction	0.00%	0.00%	4.72%	95.28%	same_as_now	0.00%	60.00%	40.00%
Year 45	GCM maximum	major_restriction	0.40%	9.68%	43.60%	46.32%	same_as_now	0.00%	62.60%	37.40%
Year 75	GCM maximum	major_restriction	0.00%	0.08%	9.60%	90.32%	same_as_now	0.00%	60.00%	40.00%
Year 100	GCM maximum	major_restriction	0.00%	0.08%	9.60%	90.32%	same_as_now	0.00%	60.00%	40.00%
Archipelago Ecoregion										
Year -10	Satellite data	no_effect	39.00%	44.60%	16.40%	0.00%	same_as_now	4.80%	53.00%	42.20%
Year 0	Satellite data	improvement	88.56%	10.43%	1.01%	0.00%	same_as_now	0.00%	100.00%	0.00%
Year 45	GCM minimum	no_effect	32.48%	41.28%	22.30%	3.94%	more	0.00%	0.00%	100.00%
Year 75	GCM minimum	minor_restriction	4.08%	24.32%	40.32%	31.28%	more	0.00%	30.00%	70.00%
Year 100	GCM minimum	minor_restriction	4.08%	24.32%	40.32%	31.28%	same_as_now	0.00%	60.00%	40.00%
Year 45	Ensemble mean	no_effect	32.48%	41.28%	22.30%	3.94%	more	0.00%	0.00%	100.00%
Year 75	Ensemble mean	minor_restriction	4.96%	25.44%	39.84%	29.76%	more	0.00%	30.00%	70.00%
Year 100	Ensemble mean	minor_restriction	4.08%	24.32%	40.32%	31.28%	same_as_now	0.00%	60.00%	40.00%
Year 45	GCM maximum	improvement	41.92%	38.40%	17.06%	2.62%	more	0.00%	0.00%	100.00%
Year 75	GCM maximum	no_effect	32.48%	41.28%	22.30%	3.94%	more	0.00%	0.00%	100.00%
Year 100	GCM maximum	minor_restriction	4.08%	24.32%	40.32%	31.28%	same_as_now	0.00%	60.00%	40.00%

Table 10 continued.

Time period	Basis	Node F2: Factor A: Habitat Threats					Node A1: Factor B: Direct Mortalities			
		Most probable outcome	P(F2= improve-ment)	P(F2= no effect)	P(F2= minor restriction)	P(F2= major restriction)	Most probable outcome	P(A1= fewer)	P(A1= same as now)	P(A1= more)
Polar Basin Divergent Ecoregion										
Year -10	Satellite data	improvement	99.68%	0.32%	0.00%	0.00%	fewer	100.00%	0.00%	0.00%
Year 0	Satellite data	no_effect	30.20%	47.24%	20.54%	2.02%	same_as_now	0.00%	100.00%	0.00%
Year 45	GCM minimum	major_restriction	0.00%	0.00%	0.00%	100.00%	same_as_now	0.00%	60.00%	40.00%
Year 75	GCM minimum	major_restriction	0.00%	0.00%	0.00%	100.00%	same_as_now	0.00%	60.60%	39.40%
Year 100	GCM minimum	major_restriction	0.00%	0.00%	0.00%	100.00%	same_as_now	0.00%	63.00%	37.00%
Year 45	Ensemble mean	major_restriction	0.00%	0.36%	9.80%	89.84%	same_as_now	0.00%	60.00%	40.00%
Year 75	Ensemble mean	major_restriction	0.00%	0.00%	0.00%	100.00%	same_as_now	0.00%	60.00%	40.00%
Year 100	Ensemble mean	major_restriction	0.00%	0.00%	0.00%	100.00%	same_as_now	0.00%	63.00%	37.00%
Year 45	GCM maximum	major_restriction	0.00%	0.36%	9.80%	89.84%	same_as_now	0.00%	60.00%	40.00%
Year 75	GCM maximum	major_restriction	0.00%	0.00%	5.08%	94.92%	same_as_now	0.00%	60.00%	40.00%
Year 100	GCM maximum	major_restriction	0.00%	0.00%	5.08%	94.92%	same_as_now	0.00%	63.60%	36.40%
Polar Basin Convergent Ecoregion										
Year -10	Satellite data	improvement	97.48%	2.52%	0.00%	0.00%	fewer	100.00%	0.00%	0.00%
Year 0	Satellite data	improvement	88.56%	10.43%	1.01%	0.00%	same_as_now	0.00%	100.00%	0.00%
Year 45	GCM minimum	minor_restriction	1.10%	14.38%	48.19%	36.32%	same_as_now	0.00%	60.00%	40.00%
Year 75	GCM minimum	major_restriction	0.00%	0.00%	23.60%	76.40%	same_as_now	0.00%	60.00%	40.00%
Year 100	GCM minimum	major_restriction	0.00%	0.00%	23.60%	76.40%	same_as_now	0.00%	60.00%	40.00%
Year 45	Ensemble mean	minor_restriction	1.25%	15.49%	49.10%	34.16%	same_as_now	0.00%	60.00%	40.00%
Year 75	Ensemble mean	major_restriction	0.00%	0.00%	17.65%	82.35%	same_as_now	0.00%	60.00%	40.00%
Year 100	Ensemble mean	major_restriction	0.00%	0.24%	22.16%	77.60%	same_as_now	0.00%	60.00%	40.00%
Year 45	GCM maximum	major_restriction	0.29%	4.22%	45.49%	50.00%	same_as_now	0.00%	60.00%	40.00%
Year 75	GCM maximum	major_restriction	0.00%	0.58%	25.18%	74.24%	same_as_now	0.00%	60.00%	40.00%
Year 100	GCM maximum	major_restriction	0.00%	0.35%	23.13%	76.52%	same_as_now	0.00%	60.00%	40.00%

Table 11. Results of the Bayesian network population stressor model, showing the most probable outcome states, and probabilities of each state, for changes in foraging habitat distribution (node D; see Figure 5).

		Node D: Change in Foraging Habitat Distribution					
Time period	Basis	Most probable outcome	P(D= improved availability)	P(D= same as now)	P(D= reduced availability)	P(D= greatly reduced availability)	P(D= unavailable)
		Seasonal Ice Ecoregion					
Year -10	Satellite data	same_as_now	50.00%	50.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	reduced_avail	0.00%	20.00%	60.00%	20.00%	0.00%
Year 45	GCM minimum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 75	GCM minimum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 100	GCM minimum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 45	Ensemble mean	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 75	Ensemble mean	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 100	Ensemble mean	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 45	GCM maximum	reduced_avail	0.00%	20.00%	60.00%	20.00%	0.00%
Year 75	GCM maximum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 100	GCM maximum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
		Archipelago Ecoregion					
Year -10	Satellite data	same_as_now	0.00%	100.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	improved_availability	60.00%	40.00%	0.00%	0.00%	0.00%
Year 45	GCM minimum	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 75	GCM minimum.	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 100	GCM minimum	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 45	Ensemble mean	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 75	Ensemble mean	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 100	Ensemble mean	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 45	GCM maximum	improved_availability	60.00%	40.00%	0.00%	0.00%	0.00%
Year 75	GCM maximum	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%
Year 100	GCM maximum	same_as_now	40.00%	60.00%	0.00%	0.00%	0.00%

Table 11 continued.

Time period	Basis	Most probable outcome	P(D= improved availability)	P(D= same as now)	P(D= reduced availability)	P(D= greatly reduced availability)	P(D= unavailable)
		Node D: Change in Foraging Habitat Distribution					
		Polar Basin Divergent Ecoregion					
Year -10	Satellite data	improved_availability	100.00%	0.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	reduced_avail	0.00%	20.00%	80.00%	0.00%	0.00%
Year 45	GCM minimum	unavailable	0.00%	0.00%	0.00%	20.00%	80.00%
Year 75	GCM minimum	unavailable	0.00%	0.00%	0.00%	20.00%	80.00%
Year 100	GCM minimum	unavailable	0.00%	0.00%	0.00%	0.00%	100.00%
Year 45	Ensemble mean	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 75	Ensemble mean	unavailable	0.00%	0.00%	0.00%	20.00%	80.00%
Year 100	Ensemble mean	unavailable	0.00%	0.00%	0.00%	0.00%	100.00%
Year 45	GCM maximum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 75	GCM maximum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
Year 100	GCM maximum	Gr_reduced_avail	0.00%	0.00%	20.00%	40.00%	40.00%
		Polar Basin Convergent Ecoregion					
Year -10	Satellite data	improved_availability	100.00%	0.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	improved_availability	60.00%	40.00%	0.00%	0.00%	0.00%
Year 45	GCM minimum	reduced_avail	0.00%	20.00%	80.00%	0.00%	0.00%
Year 75	GCM minimum	reduced_avail	0.00%	0.00%	100.00%	0.00%	0.00%
Year 100	GCM minimum	reduced_avail	0.00%	0.00%	100.00%	0.00%	0.00%
Year 45	Ensemble mean	reduced_avail	0.00%	30.00%	70.00%	0.00%	0.00%
Year 75	Ensemble mean	reduced_avail	0.00%	0.00%	70.00%	30.00%	0.00%
Year 100	Ensemble mean	reduced_avail	0.00%	20.00%	60.00%	20.00%	0.00%
Year 45	GCM maximum	reduced_avail	0.00%	30.00%	70.00%	0.00%	0.00%
Year 75	GCM maximum	reduced_avail	0.00%	20.00%	60.00%	20.00%	0.00%
Year 100	GCM maximum	reduced_avail	0.00%	20.00%	60.00%	20.00%	0.00%

Table 12. Results of the Bayesian network population stressor model, showing the most probable outcome states, and probabilities of each state, for disease/predation and other disturbance factors variables (nodes A4, A6; see Figure 5).

		Node A4: Factor C: Disease, predation			Node A6: Factor E: Other factors (natural or man-made)				
Time period	Basis	Most probable outcome	P(A4= same as now)	P(A4= worse)	Most probable outcome	P(A6= improve-ment)	P(A6= no effect)	P(A6= minor restriction)	P(A6= major restriction)
Seasonal Ice Ecoregion									
Year -10	Satellite data	same_as_now	100.00%	0.00%	improvement	84.80%	15.20%	0.00%	0.00%
Year 0	Satellite data	same_as_now	100.00%	0.00%	no_effect	0.00%	100.00%	0.00%	0.00%
Year 45	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	13.00%	87.00%
Year 75	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	13.00%	87.00%
Year 75	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	13.00%	87.00%
Year 75	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Archipelago Ecoregion									
Year -10	Satellite data	same_as_now	100.00%	0.00%	major_restriction	4.80%	20.00%	34.80%	40.40%
Year 0	Satellite data	same_as_now	100.00%	0.00%	no_effect	0.00%	100.00%	0.00%	0.00%
Year 45	GCM minimum	worse	30.00%	70.00%	major_restriction	0.00%	0.00%	28.00%	72.00%
Year 75	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	Ensemble mean	worse	30.00%	70.00%	major_restriction	0.00%	0.00%	28.00%	72.00%
Year 75	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	GCM maximum	worse	30.00%	70.00%	major_restriction	0.00%	0.00%	28.00%	72.00%
Year 75	GCM maximum	worse	30.00%	70.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%

Table 12 continued.

Time period	Basis	Node A4: Factor C: Disease, predation			Node A6: Factor E: Other factors (natural or man-made)				
		Most probable outcome	P(A4= same as now)	P(A4= worse)	Most probable outcome	P(A6= improve-ment)	P(A6= no effect)	P(A6= minor restriction)	P(A6= major restriction)
Polar Basin Divergent Ecoregion									
Year -10	Satellite data	same_as_now	100.00%	0.00%	improvement	100.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	100.00%	0.00%	no_effect	0.00%	100.00%	0.00%	0.00%
Year 45	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	3.00%	97.00%
Year 100	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	15.00%	85.00%
Year 45	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	15.00%	85.00%
Year 45	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	18.00%	82.00%
Polar Basin Convergent Ecoregion									
Year -10	Satellite data	same_as_now	100.00%	0.00%	improvement	100.00%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	100.00%	0.00%	no_effect	0.00%	100.00%	0.00%	0.00%
Year 45	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM minimum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	Ensemble mean	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 45	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 75	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%
Year 100	GCM maximum	worse	0.00%	100.00%	major_restriction	0.00%	0.00%	0.00%	100.00%

Table 13. Results of the Bayesian network population stressor model, showing the most probable outcome states, and probabilities of each state, for reproduction and vital rates (nodes U, L2; see Figure 5).

		Node U: Reproduction				Node L2: Vital Rates			
Time period	Basis	Most probable outcome	P(U= increased)	P(U= same as now)	P(U= decreased)	Most probable outcome	P(L2 =improve)	P(L2= same as now)	P(L2= decline)
		Seasonal Ice Ecoregion							
Year -10	Satellite data	increased	59.68%	33.42%	6.90%	improve	92.53%	7.00%	0.47%
Year 0	Satellite data	same_as_now	25.59%	41.59%	32.82%	same_as_now	27.38%	41.72%	30.90%
Year 45	GCM minimum	decreased	1.78%	23.47%	74.75%	decline	0.25%	7.04%	92.71%
Year 75	GCM minimum	decreased	0.38%	20.76%	78.87%	decline	0.03%	1.47%	98.50%
Year 100	GCM minimum	decreased	0.38%	20.76%	78.87%	decline	0.03%	1.47%	98.50%
Year 45	Ensemble mean	decreased	1.78%	23.47%	74.75%	decline	0.25%	7.04%	92.71%
Year 75	Ensemble mean	decreased	0.38%	20.76%	78.87%	decline	0.03%	1.47%	98.50%
Year 100	Ensemble mean	decreased	0.38%	20.76%	78.87%	decline	0.03%	1.47%	98.50%
Year 45	GCM maximum	decreased	5.67%	30.90%	63.43%	decline	1.01%	22.54%	76.45%
Year 75	GCM maximum	decreased	0.78%	21.57%	77.65%	decline	0.05%	3.07%	96.87%
Year 100	GCM maximum	decreased	0.78%	21.57%	77.65%	decline	0.05%	3.07%	96.87%
		Archipelago Ecoregion							
Year -10	Satellite data	same_as_now	34.41%	45.14%	20.44%	same_as_now	39.94%	47.09%	12.97%
Year 0	Satellite data	increased	57.07%	34.96%	7.96%	improve	86.86%	12.04%	1.11%
Year 45	GCM minimum	same_as_now	30.18%	43.98%	25.84%	same_as_now	33.47%	45.72%	20.80%
Year 75	GCM minimum	decreased	10.62%	36.67%	52.71%	decline	5.17%	35.07%	59.76%
Year 100	GCM minimum	decreased	10.62%	36.67%	52.71%	decline	5.17%	35.07%	59.76%
Year 45	Ensemble mean	same_as_now	30.18%	43.98%	25.84%	same_as_now	33.47%	45.72%	20.80%
Year 75	Ensemble mean	decreased	11.35%	37.15%	51.50%	decline	6.07%	35.97%	57.96%
Year 100	Ensemble mean	decreased	10.62%	36.67%	52.71%	decline	5.17%	35.07%	59.76%
Year 45	GCM maximum	same_as_now	35.03%	43.12%	21.85%	improve	42.54%	41.66%	15.80%
Year 75	GCM maximum	same_as_now	30.18%	43.98%	25.84%	same_as_now	33.47%	45.72%	20.80%
Year 100	GCM maximum	decreased	10.62%	36.67%	52.71%	decline	5.17%	35.07%	59.76%

Table 13 continued.

Time period	Basis	Node U: Reproduction				Node L2: Vital Rates			
		Most probable outcome	P(U= increased)	P(U= same as now)	P(U= decreased)	Most probable outcome	P(L2 =improve)	P(L2= same as now)	P(L2= decline)
				Polar Basin Divergent Ecoregion					
Year -10	Satellite data	increased	90.93%	9.07%	0.00%	improve	99.72%	0.28%	0.00%
Year 0	Satellite data	same_as_now	10.57%	77.96%	11.47%	same_as_now	30.20%	53.67%	16.12%
Year 45	GCM minimum	decreased	0.00%	0.00%	100.00%	decline	0.00%	0.00%	100.00%
Year 75	GCM minimum	decreased	0.00%	0.00%	100.00%	decline	0.00%	0.00%	100.00%
Year 100	GCM minimum	decreased	0.00%	0.00%	100.00%	decline	0.00%	0.00%	100.00%
Year 45	Ensemble mean	decreased	0.00%	1.28%	98.72%	decline	0.00%	3.09%	96.91%
Year 75	Ensemble mean	decreased	0.00%	0.00%	100.00%	decline	0.00%	0.00%	100.00%
Year 100	Ensemble mean	decreased	0.00%	0.00%	100.00%	decline	0.00%	0.00%	100.00%
Year 45	GCM maximum	decreased	0.00%	1.28%	98.72%	decline	0.00%	3.09%	96.91%
Year 75	GCM maximum	decreased	0.00%	0.61%	99.39%	decline	0.00%	1.44%	98.56%
Year 100	GCM maximum	decreased	0.00%	0.61%	99.39%	decline	0.00%	1.44%	98.56%
				Polar Basin Convergent Ecoregion					
Year -10	Satellite data	increased	100.00%	0.00%	0.00%	improve	97.98%	2.02%	0.00%
Year 0	Satellite data	increased	68.30%	31.34%	0.36%	improve	89.62%	9.73%	0.66%
Year 45	GCM minimum	decreased	0.15%	30.35%	69.49%	decline	0.91%	27.51%	71.58%
Year 75	GCM minimum	decreased	0.00%	22.83%	77.17%	decline	0.00%	7.04%	92.96%
Year 100	GCM minimum	decreased	0.00%	22.83%	77.17%	decline	0.00%	7.04%	92.96%
Year 45	Ensemble mean	decreased	7.45%	40.74%	51.81%	decline	2.03%	29.91%	68.06%
Year 75	Ensemble mean	decreased	0.00%	22.12%	77.88%	decline	0.00%	5.26%	94.74%
Year 100	Ensemble mean	decreased	1.82%	32.73%	65.45%	decline	0.13%	7.24%	92.63%
Year 45	GCM maximum	decreased	4.58%	36.77%	58.65%	decline	0.68%	18.32%	81.00%
Year 75	GCM maximum	decreased	2.13%	33.19%	64.68%	decline	0.16%	8.51%	91.33%
Year 100	GCM maximum	decreased	1.92%	32.88%	65.20%	decline	0.14%	7.65%	92.21%

Table 14. Projected outcomes from Bayesian network population stressor model showing probabilities of overall outcome states resulting when all human factors were fixed at 'same as now' or 'fewer than now.'

		"Influence Run" #1						"Influence Run" #2					
		Outcome forcing Node A1 = "same as now" and Node A6 = "no effect", for Years 45, 75, 100						Outcome forcing Node A1 = "fewer" and Node A6 = "improvement", for Years 45, 75, 100					
		Node D1: Overall Population Outcome						Node D1: Overall Population Outcome					
Time period	**Basis**	**most-prob D1**	**P(D1= larger)**	**P(D1= same as now)**	**P(D1= smaller)**	**P(D1= rare)**	**P(D1= extinct)**	**most-prob D1**	**P(D1= larger)**	**P(D1= same as now)**	**P(D1= smaller)**	**P(D1= rare)**	**P(D1= extinct)**
Seasonal Ice Ecoregion													
Year -10	Satellite data	larger	93.92%	5.75%	0.30%	0.02%	0.00%	larger	93.92%	5.75%	0.30%	0.02%	0.00%
Year 0	Satellite data	same_as_now	21.85%	43.72%	18.98%	8.37%	7.07%	same_as_now	21.85%	43.72%	18.98%	8.37%	7.07%
Year 45	GCM minimum	extinct	0.10%	1.46%	22.80%	21.20%	54.40%	extinct	0.11%	8.43%	31.70%	14.00%	45.80%
Year 75	GCM minimum	extinct	0.01%	0.24%	16.20%	20.20%	63.30%	extinct	0.01%	3.89%	27.90%	14.70%	53.50%
Year 100	GCM minimum	extinct	0.01%	0.52%	18.60%	18.70%	62.20%	extinct	0.10%	4.98%	28.10%	13.30%	53.50%
Year 45	Ensemble mean	extinct	0.10%	1.46%	22.80%	21.20%	54.40%	extinct	0.11%	8.43%	31.70%	14.00%	45.80%
Year 75	Ensemble mean	extinct	0.01%	0.24%	16.20%	20.20%	63.30%	extinct	0.01%	3.89%	27.90%	14.70%	53.50%
Year 100	Ensemble mean	extinct	0.01%	0.24%	16.20%	20.20%	63.30%	extinct	0.01%	3.89%	27.90%	14.70%	53.50%
Year 45	GCM maximum	smaller	0.45%	5.16%	39.50%	22.80%	32.00%	smaller	0.46%	21.10%	40.30%	11.90%	26.30%
Year 75	GCM maximum	extinct	0.02%	0.52%	18.50%	20.80%	60.20%	extinct	0.02%	5.20%	29.50%	14.50%	50.80%
Year 100	GCM maximum	extinct	0.02%	0.52%	18.50%	20.80%	60.20%	extinct	0.02%	5.20%	29.50%	14.50%	50.80%
Archipelago Ecoregion													
Year -10	Satellite data	same_as_now	22.51%	34.73%	31.48%	8.72%	2.56%	same_as_now	22.51%	34.73%	31.48%	8.72%	2.56%
Year 0	Satellite data	larger	69.48%	29.26%	1.06%	0.19%	0.00%	larger	69.48%	29.26%	1.06%	0.19%	0.00%
Year 45	GCM minimum	smaller	19.70%	29.40%	39.70%	8.90%	2.26%	same_as_now	24.30%	44.10%	25.40%	4.62%	1.55%
Year 75	GCM minimum	smaller	2.54%	10.10%	46.40%	19.00%	22.00%	smaller	2.55%	31.80%	38.50%	9.30%	17.80%
Year 100	GCM minimum	smaller	2.54%	10.10%	46.40%	19.00%	22.00%	smaller	2.55%	31.80%	38.50%	9.30%	17.80%
Year 45	Ensemble mean	smaller	19.70%	29.40%	39.70%	8.90%	2.26%	same_as_now	24.30%	44.10%	25.40%	4.62%	1.55%
Year 75	Ensemble mean	smaller	2.99%	10.50%	46.50%	23.50%	16.50%	smaller	2.99%	32.10%	38.90%	13.20%	12.70%
Year 100	Ensemble mean	smaller	2.54%	10.10%	46.40%	19.00%	22.00%	smaller	2.55%	31.80%	38.50%	9.30%	17.80%
Year 45	GCM maximum	smaller	25.10%	29.90%	36.80%	6.72%	1.55%	same_as_now	30.00%	42.10%	23.40%	3.43%	1.03%
Year 75	GCM maximum	smaller	19.70%	29.40%	39.70%	8.90%	2.26%	same_as_now	24.30%	44.10%	25.40%	4.62%	1.55%
Year 100	GCM maximum	smaller	2.54%	10.10%	46.40%	19.00%	22.00%	smaller	2.55%	31.80%	38.50%	9.30%	17.80%

Table 14 continued.

		"Influence Run" #1: Outcome forcing Node A1 = "same as now" and Node A6 = "no effect", for Years 45, 75, 100 — Node D1: Overall Population Outcome						"Influence Run" #2: Outcome forcing Node A1 = "fewer" and Node A6 = "improvement", for Years 45, 75, 100 — Node D1: Overall Population Outcome					
Time period	Basis	most-prob D1	P(D1= larger)	P(D1= same as now)	P(D1= smaller)	P(D1= rare)	P(D1= extinct)	most-prob D1	P(D1= larger)	P(D1= same as now)	P(D1= smaller)	P(D1= rare)	P(D1= extinct)
Polar Basin Divergent Ecoregion													
Year -10	Satellite data	larger	99.78%	0.22%	0.00%	0.00%	0.00%	larger	99.78%	0.22%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	24.16%	56.60%	13.36%	4.73%	1.14%	same_as_now	24.16%	56.60%	13.36%	4.73%	1.14%
Year 45	GCM minimum	extinct	0.00%	0.00%	15.90%	25.30%	58.80%	extinct	0.00%	2.70%	29.20%	19.10%	49.00%
Year 75	GCM minimum	extinct	0.00%	0.00%	15.90%	25.30%	58.80%	extinct	0.00%	2.70%	29.20%	19.10%	49.00%
Year 100	GCM minimum	extinct	0.00%	0.00%	15.90%	25.30%	58.80%	extinct	0.00%	2.70%	29.20%	19.10%	49.00%
Year 45	Ensemble mean	extinct	0.00%	0.53%	20.10%	26.00%	53.40%	extinct	0.00%	5.28%	31.90%	18.50%	44.30%
Year 75	Ensemble mean	extinct	0.00%	0.00%	15.90%	25.30%	58.80%	extinct	0.00%	2.70%	29.20%	19.10%	49.00%
Year 100	Ensemble mean	extinct	0.00%	0.00%	15.90%	25.30%	58.80%	extinct	0.00%	2.70%	29.20%	19.10%	49.00%
Year 45	GCM maximum	extinct	0.00%	0.53%	20.10%	26.00%	53.40%	extinct	0.00%	5.28%	31.90%	18.50%	44.30%
Year 75	GCM maximum	extinct	0.00%	0.22%	18.00%	25.70%	56.10%	extinct	0.00%	3.91%	30.60%	18.80%	46.70%
Year 100	GCM maximum	extinct	0.00%	0.22%	18.00%	25.70%	56.10%	extinct	0.00%	3.91%	30.60%	18.80%	46.70%
Polar Basin Convergent Ecoregion													
Year -10	Satellite data	larger	98.39%	1.61%	0.00%	0.00%	0.00%	larger	98.39%	1.61%	0.00%	0.00%	0.00%
Year 0	Satellite data	larger	71.69%	27.49%	0.63%	0.19%	0.00%	larger	71.69%	27.49%	0.63%	0.19%	0.00%
Year 45	GCM minimum	smaller	0.46%	6.31%	44.10%	30.70%	18.40%	smaller	0.46%	24.70%	43.20%	17.80%	13.80%
Year 75	GCM minimum	extinct	0.00%	1.13%	24.60%	22.30%	51.90%	extinct	0.00%	8.56%	33.90%	14.00%	43.50%
Year 100	GCM minimum	extinct	0.00%	1.13%	24.60%	22.30%	51.90%	extinct	0.00%	8.56%	33.90%	14.00%	43.50%
Year 45	Ensemble mean	smaller	0.95%	7.12%	44.70%	30.40%	16.80%	smaller	0.96%	26.10%	42.70%	17.80%	12.50%
Year 75	Ensemble mean	extinct	0.00%	0.82%	23.00%	26.10%	50.00%	extinct	0.00%	6.98%	33.90%	17.70%	41.50%
Year 100	Ensemble mean	extinct	0.04%	1.24%	24.30%	22.10%	52.40%	extinct	0.04%	8.54%	33.40%	14.00%	44.00%
Year 45	GCM maximum	smaller	0.28%	3.47%	37.70%	34.60%	24.00%	smaller	0.29%	16.70%	43.30%	21.40%	18.30%
Year 75	GCM maximum	rare	0.05%	1.38%	28.50%	35.60%	34.50%	smaller	0.05%	9.12%	39.40%	24.30%	27.10%
Year 100	GCM maximum	extinct	0.04%	1.28%	25.60%	26.40%	46.60%	extinct	0.05%	8.73%	35.40%	17.30%	38.50%

Table 15. Projected outcomes from Bayesian network population stressor model showing probabilities of overall outcome states resulting when all human factors were fixed at uniform.

This means we made no assumptions about whether human factors would have more or less influences on polar bears in the future. We allowed total uncertainty in these nodes.

		"Influence Run" #3					
		Outcome forcing all input nodes to uniform (default prior) probabilities, except ice nodes N, B & C, and Ecoregion node M, for Years 45, 75, 100					
		Node D1: Overall Population Outcome					
Time period	Basis	most-prob D1	P(D1= larger)	P(D1= same as now)	P(D1= smaller)	P(D1= rare)	P(D1= extinct)
Seasonal Ice Ecoregion							
Year -10	Satellite data	larger	93.92%	5.75%	0.30%	0.02%	0.00%
Year 0	Satellite data	same_as_now	21.85%	43.72%	18.98%	8.37%	7.07%
Year 45	GCM minimum	extinct	0.25%	2.61%	14.70%	13.30%	69.10%
Year 75	GCM minimum	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Year 100	GCM minimum	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Year 45	Ensemble mean	extinct	0.25%	2.61%	14.70%	13.30%	69.10%
Year 75	Ensemble mean	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Year 100	Ensemble mean	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Year 45	GCM maximum	extinct	1.06%	7.63%	27.20%	16.50%	47.60%
Year 75	GCM maximum	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Year 100	GCM maximum	extinct	0.05%	1.42%	11.90%	12.70%	74.00%
Archipelago Ecoregion							
Year -10	Satellite data	same_as_now	22.51%	34.73%	31.48%	8.72%	2.56%
Year 0	Satellite data	larger	69.48%	29.26%	1.06%	0.19%	0.00%
Year 45	GCM minimum	smaller	6.34%	17.20%	39.80%	15.30%	21.40%
Year 75	GCM minimum	extinct	2.86%	12.50%	34.00%	16.00%	34.60%
Year 100	GCM minimum	extinct	2.86%	12.50%	34.00%	16.00%	34.60%
Year 45	Ensemble mean	smaller	6.34%	17.20%	39.80%	15.30%	21.40%
Year 75	Ensemble mean	extinct	2.86%	12.50%	34.00%	16.00%	34.60%
Year 100	Ensemble mean	extinct	2.86%	12.50%	34.00%	16.00%	34.60%
Year 45	GCM maximum	smaller	8.55%	19.90%	41.60%	13.70%	16.20%
Year 75	GCM maximum	smaller	6.34%	17.20%	39.80%	15.30%	21.40%
Year 100	GCM maximum	extinct	2.86%	12.50%	34.00%	16.00%	34.60%

Table 15 continued.

		"Influence Run" #3					
		Outcome forcing all input nodes to uniform (default prior) probabilities, except ice nodes N, B & C, and Ecoregion node M, for Years 45, 75, 100					
		Node D1: Overall Population Outcome					
Time period	**Basis**	**most-prob D1**	**P(D1= larger)**	**P(D1= same as now)**	**P(D1= smaller)**	**P(D1= rare)**	**P(D1= extinct)**
		Polar Basin Divergent Ecoregion					
Year -10	Satellite data	larger	99.78%	0.22%	0.00%	0.00%	0.00%
Year 0	Satellite data	same_as_now	24.16%	56.60%	13.36%	4.73%	1.14%
Year 45	GCM minimum	extinct	0.00%	0.59%	8.78%	11.30%	79.30%
Year 75	GCM minimum	extinct	0.00%	0.53%	8.53%	11.20%	79.70%
Year 100	GCM minimum	extinct	0.00%	0.53%	8.53%	11.20%	79.70%
Year 45	Ensemble mean	extinct	0.17%	2.47%	14.70%	13.50%	69.20%
Year 75	Ensemble mean	extinct	0.00%	0.59%	8.78%	11.30%	79.30%
Year 100	Ensemble mean	extinct	0.00%	0.53%	8.53%	11.20%	79.70%
Year 45	GCM maximum	extinct	0.17%	2.47%	14.70%	13.50%	69.20%
Year 75	GCM maximum	extinct	0.03%	1.36%	11.80%	12.70%	74.10%
Year 100	GCM maximum	extinct	0.03%	1.36%	11.80%	12.70%	74.10%
		Polar Bear Convergent Ecoregion					
Year -10	Satellite data	larger	98.39%	1.61%	0.00%	0.00%	0.00%
Year 0	Satellite data	larger	71.69%	27.49%	0.63%	0.19%	0.00%
Year 45	GCM minimum	extinct	0.91%	8.60%	30.20%	17.50%	42.80%
Year 75	GCM minimum	extinct	0.14%	4.15%	22.60%	17.40%	55.70%
Year 100	GCM minimum	extinct	0.14%	4.15%	22.60%	17.40%	55.70%
Year 45	Ensemble mean	extinct	1.31%	9.28%	30.90%	17.30%	41.20%
Year 75	Ensemble mean	extinct	0.10%	3.16%	18.80%	15.70%	62.30%
Year 100	Ensemble mean	extinct	0.34%	4.29%	21.10%	16.00%	58.30%
Year 45	GCM maximum	extinct	0.46%	5.31%	24.10%	17.00%	53.10%
Year 75	GCM maximum	extinct	0.34%	4.29%	21.10%	16.00%	58.30%
Year 100	GCM maximum	extinct	0.34%	4.29%	21.10%	16.00%	58.30%

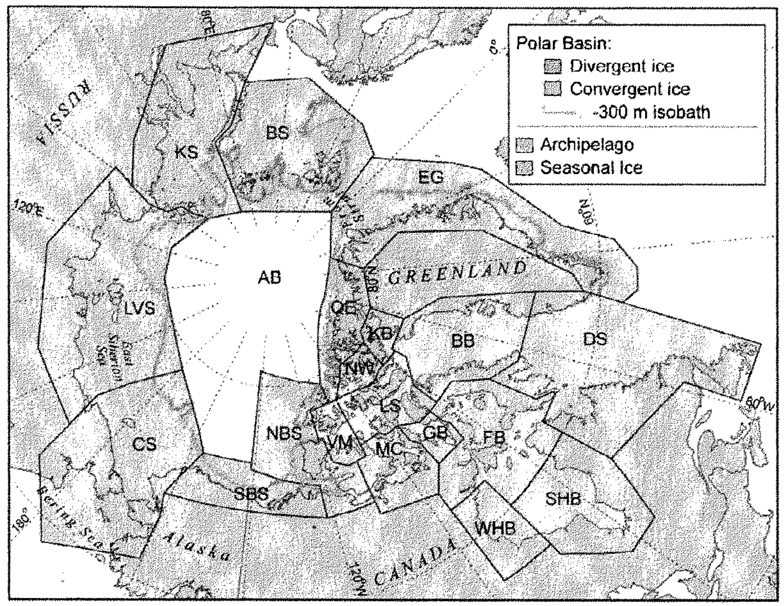


Figure 1. Map of four polar bear ecoregions to which we refer in this report. Ecoregions were established by grouping recognized subpopulations which share seasonal patterns of ice motion and distribution.

The polar basin Divergent Ice Ecoregion (purple) includes: Southern Beaufort Sea (SBS), Chukchi Sea (CS), Laptev Sea (LVS), Kara Sea (KS), and the Barents Sea (BS). The polar basin Convergent Ice Ecoregion (blue) includes: East Greenland (EG), Queen Elizabeth (QE), Northern Beaufort Sea (NBS). The Seasonal Ice Ecoregion (Green) includes: Southern Hudson Bay (SHB), Western Hudson Bay (WHB), Foxe Basin (FB), Davis Strait (DS), and Baffin Bay (BB). The Archipelago Ecoregion (yellow) includes: Gulf of Boothia (GB), M'Clintock Channel (MC), Lancaster Sound (LS, orange), Viscount-Melville Sound (VM), Norwegian Bay (NW), and Kane Basin (KB).

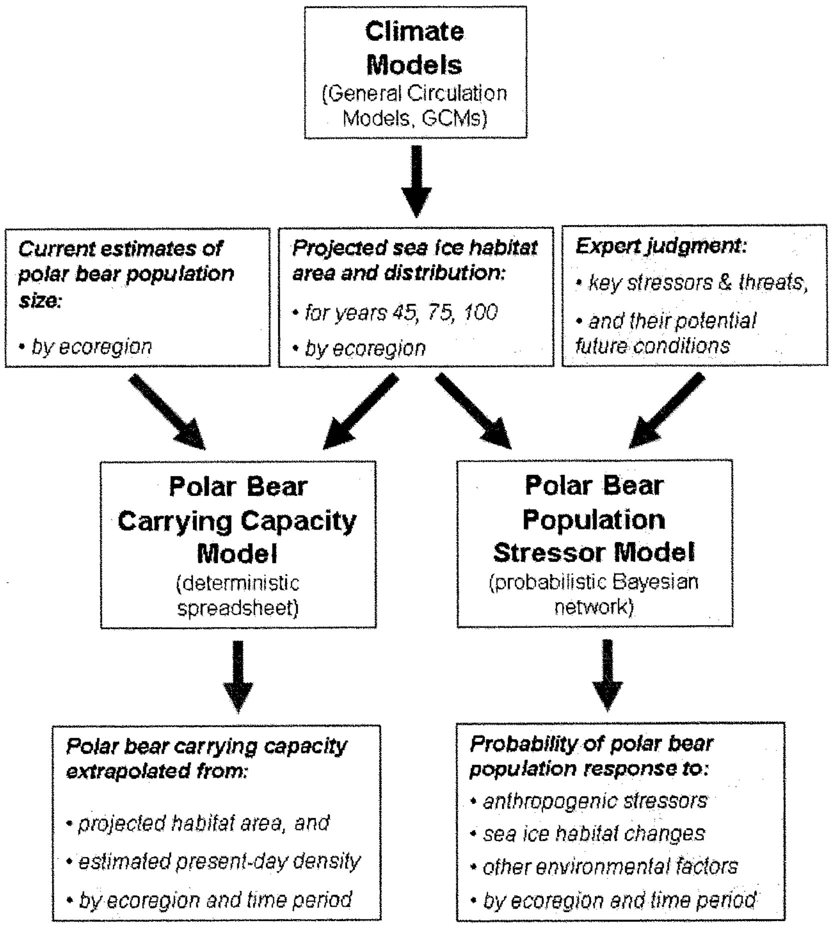


Figure 2. Linkages followed in this report, from available information on sea ice polar bears and other environmental correlates, and leading to projections of future polar bear carrying capacity and overall population outcome.

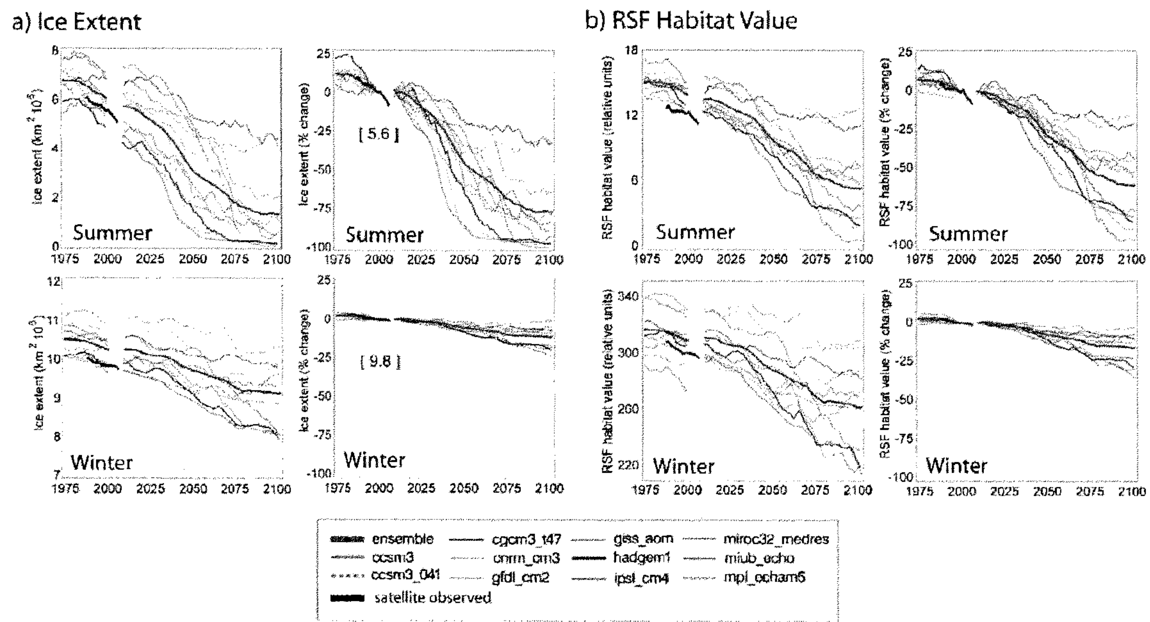


Figure 3. (a) Average summer and winter sea ice extent in the entire polar basin (divergent and convergent regions) expressed in square km (left) and as a percent change relative to each model's 1990-1999 mean for 20th century hindcasts (right). (b) Average RSF habitat values for summer and winter expressed in raw RSF units (left) and percent change to each model's 1990-1999 mean for the 20th century hindcasts (right).

Black line is the PMW satellite record of actual observations. Numbers in brackets are seasonal mean of values for 1990-1999. Note most hindcast model results overestimated the amount of habitat available during the observation period.

Figure 4. The basic influence diagram for the Bayesian network polar bear population stressor model showing the role of 4 listing factor categories used by U.S. Fish and Wildlife Service.

The final output node, overall population outcome, represents expected the joint polar bear population numerical and distribution responses to multiple stressors and environmental conditions.

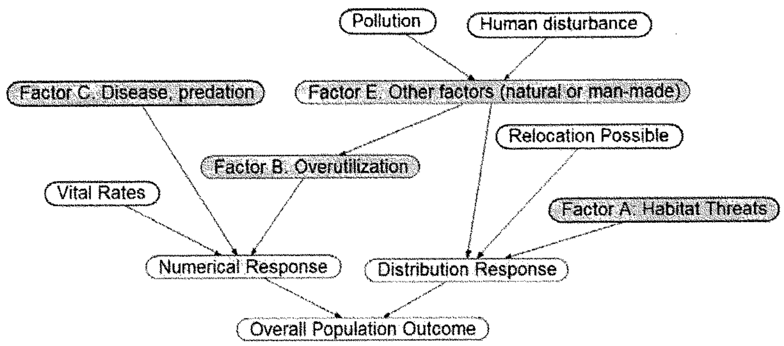


Figure 5. The full Bayesian network population stressor model developed to evaluate overall population outcome.

Input nodes are set to initial uniform probabilities. The model is solved by specifying input node values for each combination of 4 geographic regions, 5 time periods, and 4 global climate modeling scenarios or data sources (input data are specified in Table 3).

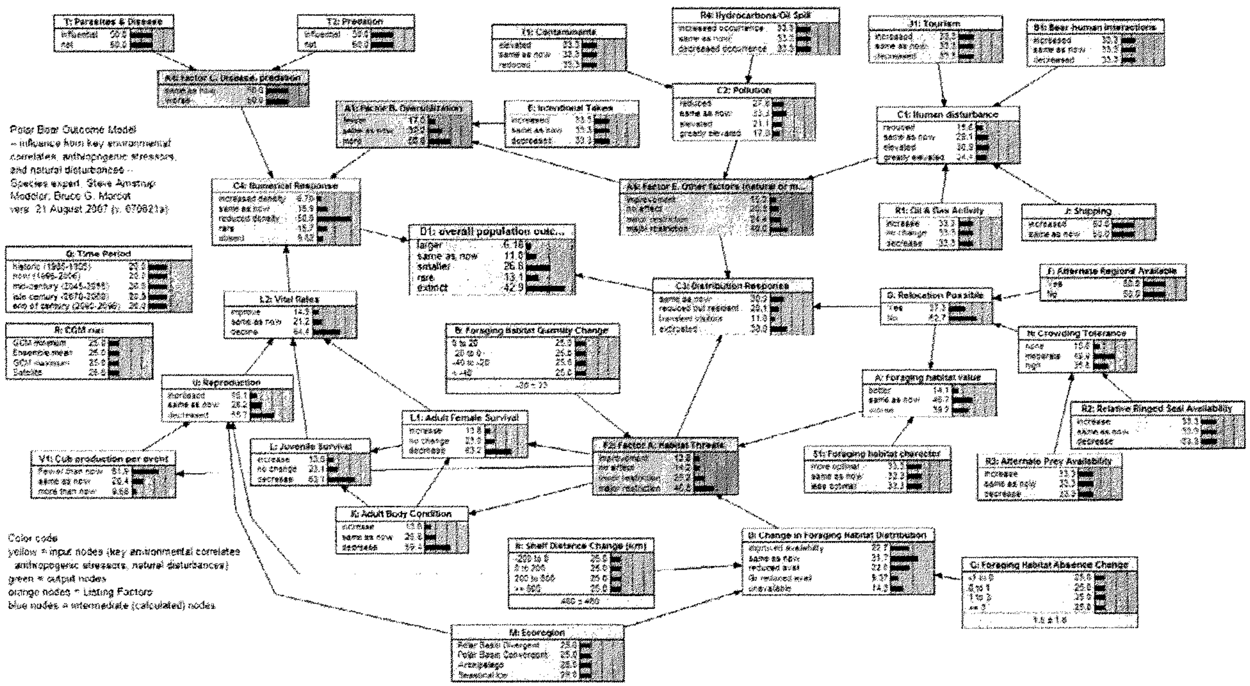


Figure 6. Annual (12-month sum) polar bear habitat area $H_{t,G}$ at t years -10 and 0 from satellite data and 0, 45, 75, and 100 from minimum, ensemble mean, and maximum global change model (GCM) runs, in four geographic regions G and all regions combined (see Table 4).

Optimal (selected) habitat areas (from resource selection function [RSF] models) are shown for the two Polar Basin regions.

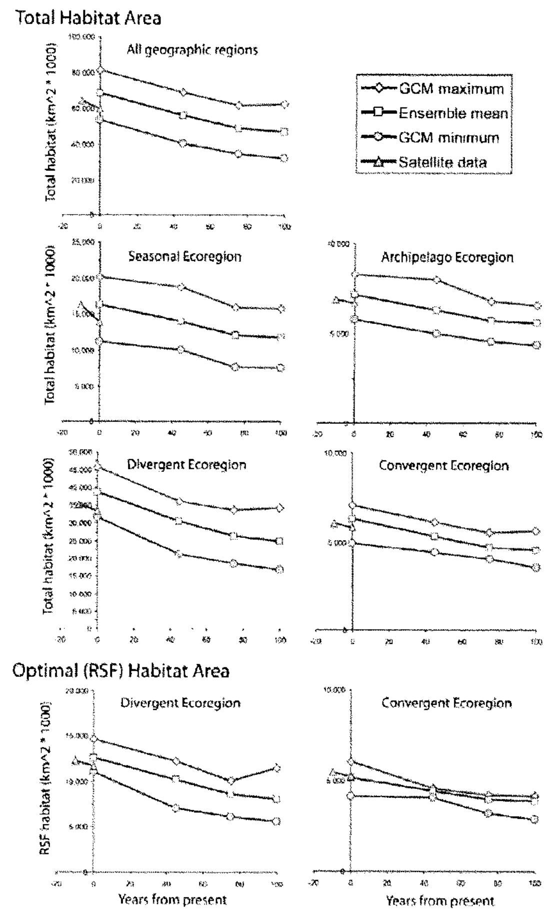


Figure 7. Percent change in polar bear habitat amounts $CH_{t,G}$ at t years -10 and 0 from satellite data and 0, 45, 75, and 100 from minimum, ensemble mean, and maximum global change model (GCM) runs, in four geographic regions G and all regions combined, normalized to 0% change at year 0 (see Table 4).

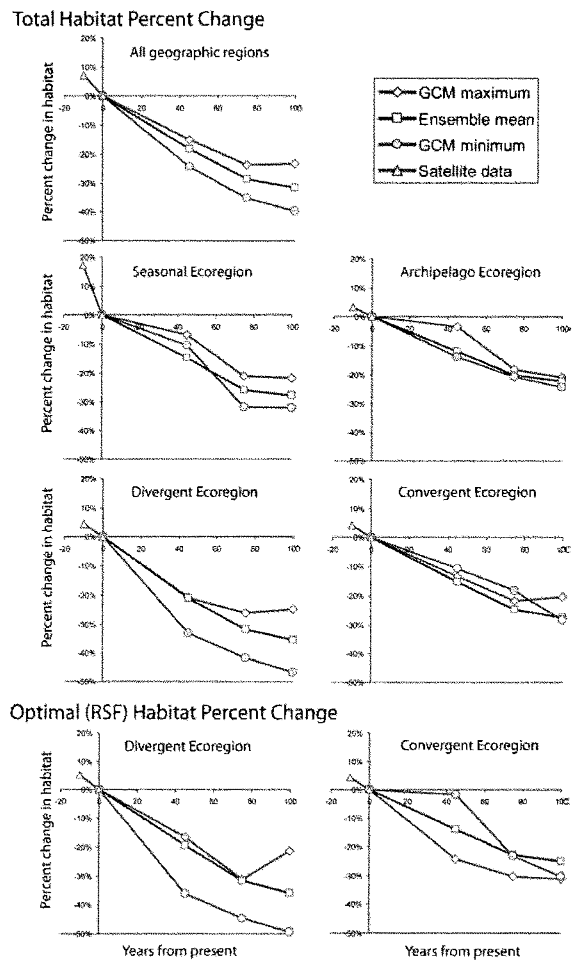


Figure 8. Normalized polar bear carrying capacity $K_{t,G}^{norm}$ at t years -10 and 0 based on habitat amount from satellite data at year -10, empirical bear counts at year 0, and habitat amounts at years 0, 45, 75, and 100 from minimum, ensemble mean, and maximum global change model (GCM) runs, in four geographic regions G and all regions combined (see Table 6).

GCM-based values are normalized to year 0 empirical counts. Note that all graphs are plotted on the same y-axis scale for comparison.

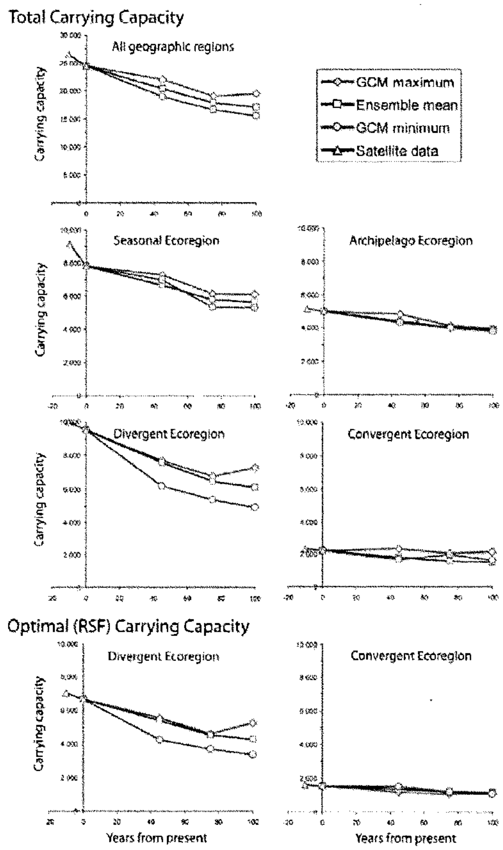
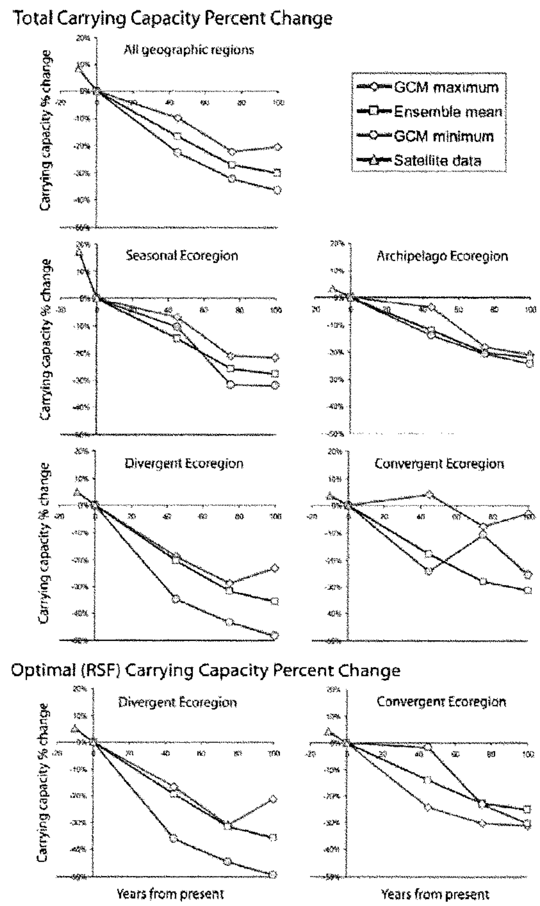


Figure 9. Polar bear carrying capacity trends $CK_{t,G}$ at t years -10 and 0 based on carrying capacity values from Figure 8, in four geographic regions G and all regions combined, normalized to 0% change at year 0 (see Table 6).



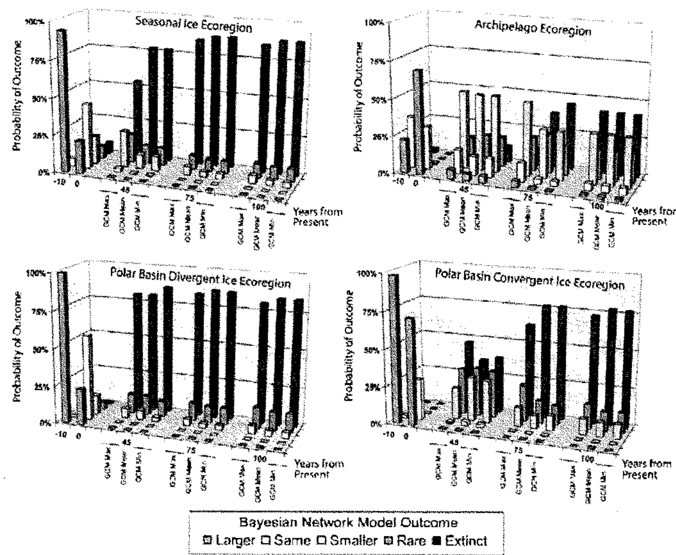


Figure 10. Projected polar bear population outcomes of Bayesian network model for 4 ecoregions at 5 time periods relative to present.

Present and prior decade (years 0 and -10) sea ice conditions were from observed record. Future ice conditions were based on the ensemble mean of 10 GCMs, and the 2 GCMs that forecasted maximum and minimum ice extent in each ecoregion at each time period. Note that strength of dominant outcomes (tallest bars) is inversely proportional to heights of competing outcomes. Outcome definitions: larger = more abundant than present (Year 0) plus distribution at least the same as at present; same = numerical and distribution responses similar to present; smaller = reduced in numbers and distribution; rare = numerically rare but occupying similar distribution, or reduced numerically but spatially represented as transient visitors, extinct =are numerically absent or distributionally extirpated.

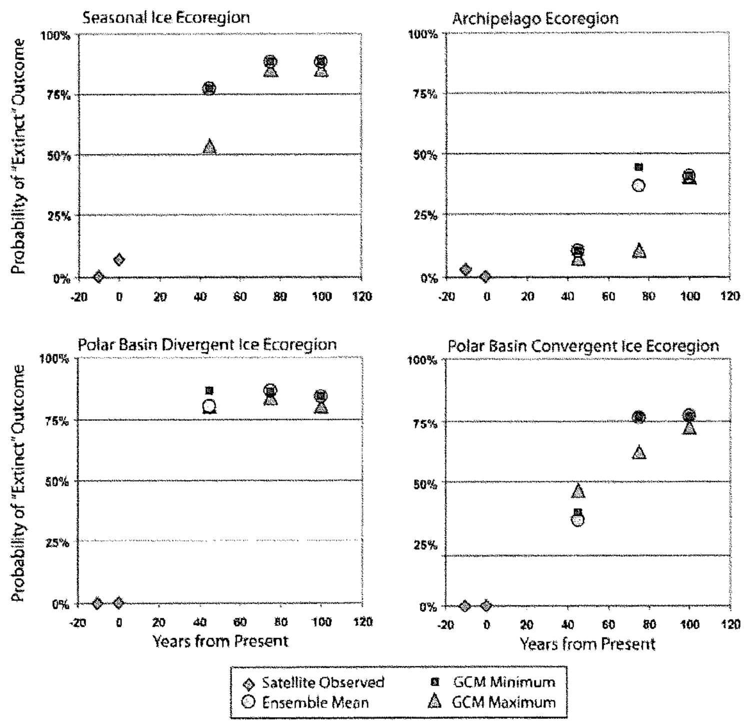


Figure 11. Projected probabilities of the "extinct" overall population outcome (node D1 in Fig. 5), from the Bayesian network population stressor model.

Projections include 4 ecoregions, and 5 time periods relative to present. Present and prior decade (years 0 and -10) sea ice conditions were from observed record. Future ice conditions were based on the ensemble mean of 10 GCMs, and the 2 GCMs that forecasted maximum and minimum ice extent in each ecoregion at each time period.

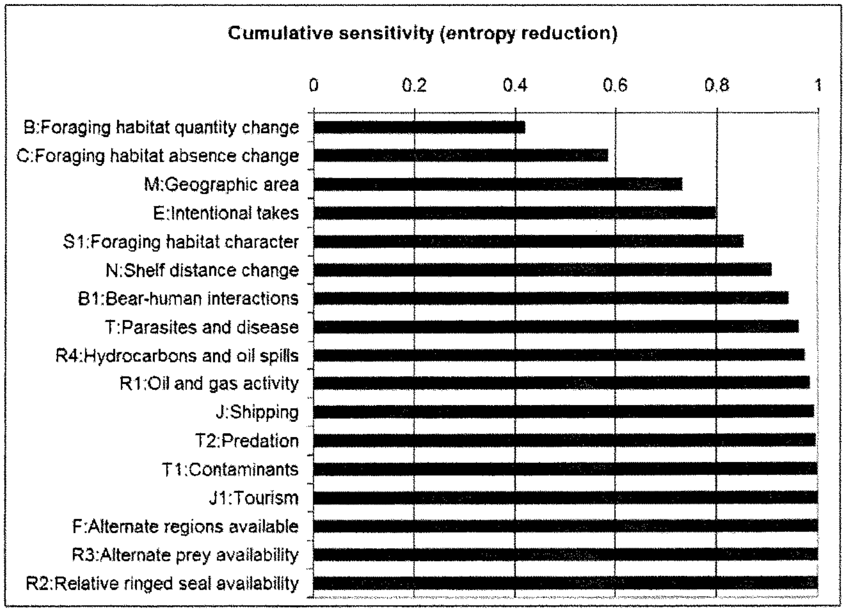


Figure 12. Cumulative sensitivity of overall population outcome (node D1, Fig. 5) to all input variables (yellow boxes, Fig. 5), in the Bayesian network population stressor model.

The 17 input variables on the vertical axis are listed, top to bottom, in decreasing order of their individual influence on overall population outcome (see Appendix 1, Sensitivity Test 1). The horizontal axis represents the cumulative proportion of total entropy reduction (mutual information) from the input variables. For example, the first two variables, foraging habitat quantity change and foraging habitat absence change, together account for 58% of all explainable entropy reduction.

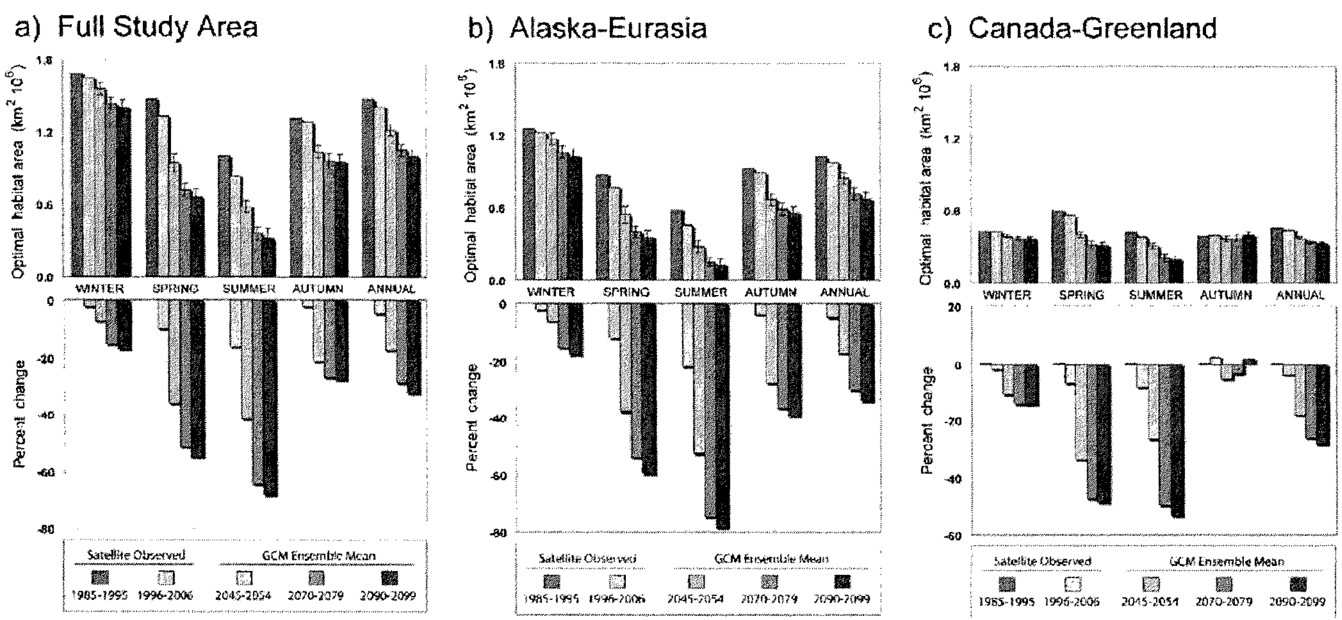


Figure 13. Mean (SE) area of optimal RSF polar bear habitat in the polar basin by season and decadal time period (top), and percentage change in the same values (bottom), from ensemble mean of 10 IPCC AR-4 general circulation models.

Note the modest changes in annual values which were used in our carrying capacity model in comparison to the spring and summer values.

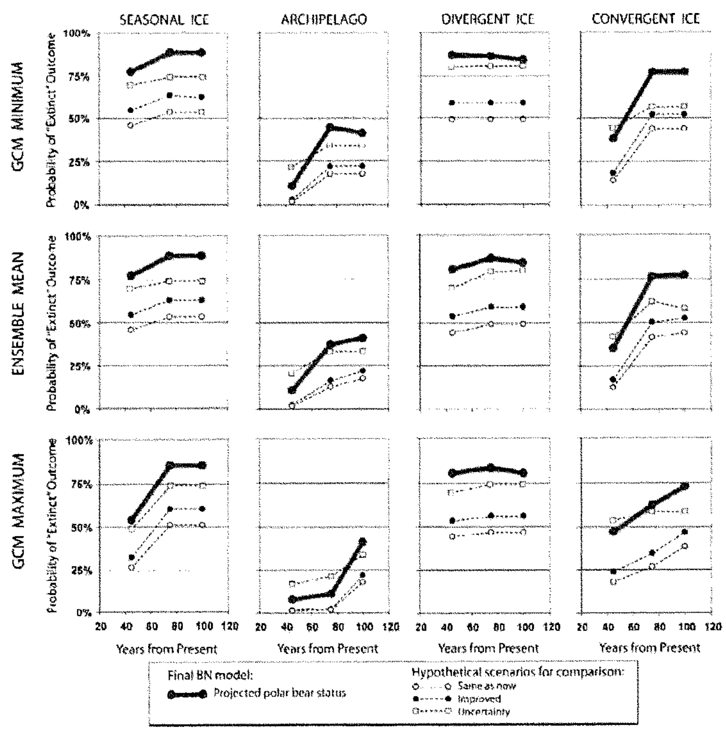


Figure 14. Probability of "extinct" outcomes projected by a Bayesian network (BN) polar bear population stressor model. Projections include 4 ecoregions, and 3 future time periods relative to present.

Future ice conditions were based on the ensemble mean of 10 GCMs, and the 2 GCMs that forecasted maximum and minimum ice extent in each ecoregion at each time period. General BN runs (thick red lines, Table 8, Figure 11) are compared to results obtained by 3 scenarios in which certain inputs were fixed: "Same" = direct mortalities (BN node A1, Figure 5) fixed at "same as now" and other human factors (node A6) at "no effect" (open circles); "Fewer" = node A1 fixed at "fewer" and node A6 at "improvement" (solid circles); and "Uncertain" = all input nodes other than those expressing quantitative sea ice conditions held at their uniform, prior probabilities (complete uncertainty) with the three ice-related nodes (N, B, and C) varying the same as the original runs (open squares).

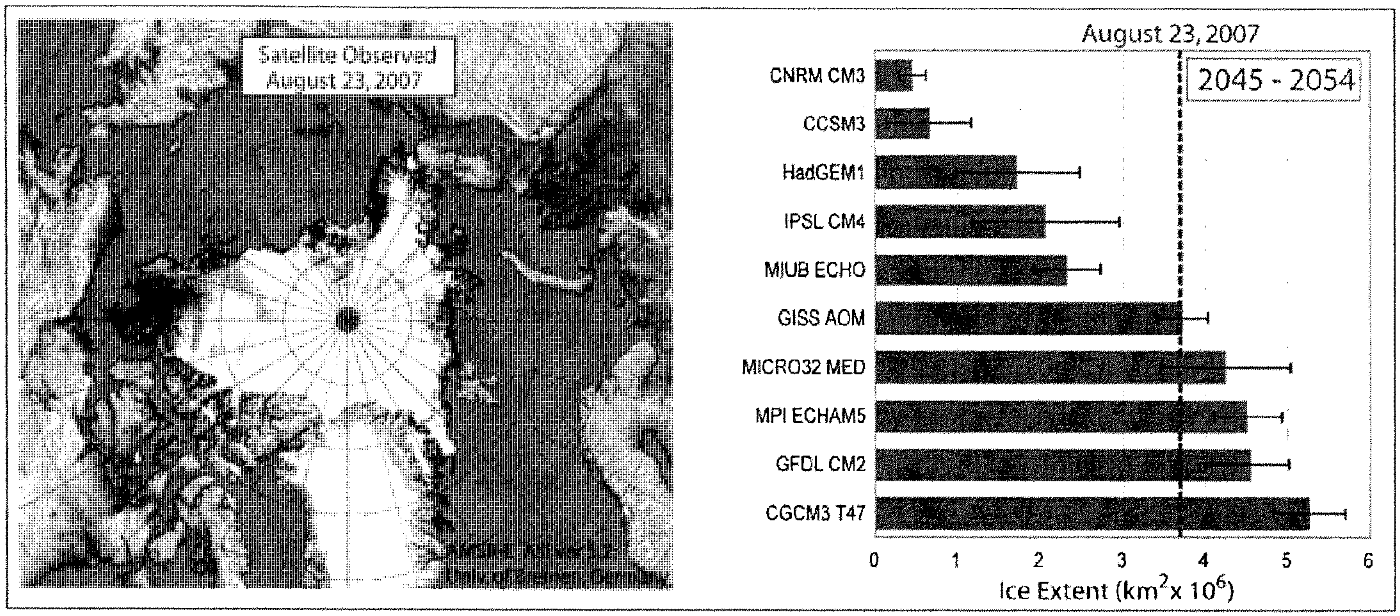


Figure 15. Area of sea ice extent (>50% ice concentration) on August 23, 2007, compared to 10 IPCC AR-4 GCM mid-century projections of ice extent for September 2045–2054 (mean ± 1 sd, n = 10 years).

Note that the 4 models which project the greatest remaining sea ice extent at mid century forecast more perennial sea ice than we have at present. Ice extent for August 23, 2007, was calculated using near-real-time ice concentration estimates derived with the NASA Team algorithm and distributed by the NSIDC (http://nsidc.org).

Appendix 1. Results of sensitivity analyses of the Bayesian network population stressor model

This appendix presents the results of conducting a series of sensitivity analyses of the Bayesian network population stressor model discussed in the text (also see Fig. 5). Sensitivity analysis reveals the degree to which selected input or summary variables influence the calculated values of a specified output variable. Presented here are results of 10 sensitivity tests on various summary and output nodes in the model (see text for explanation of calculations). Note that mutual information is also called entropy reduction. All tests were conducted using the Bayesian network modeling software package Netica (Norsys, Inc.).

SENSITIVITY GROUP 1: SENSITIVITY OF OVERALL POPULATION OUTCOME

Sensitivity Test 1. Sensitivity of node D1:Overall Population Outcome to all input nodes

Node	Mutual Info	Node title
B	0.11624	Foraging Habitat Quantity Change
C	0.04591	Foraging Habitat Absence Change
M	0.04003	Geographic Area
E	0.01837	Intentional Takes
S1	0.01569	Foraging habitat character
N	0.01325	Shelf Distance Change (km)
B1	0.00939	Bear-human interactions
T	0.00546	Parasites & Disease
R4	0.00308	Hydrocarbons/Oil Spill
R1	0.00289	Oil & Gas Activity
J	0.00224	Shipping
T2	0.00100	Predation
T1	0.00082	Contaminants
J1	0.00046	Tourism
F	0.00000	Alternate Regions Available
R3	0.00000	Alternate Prey Availability
R2	0.00000	Relative Ringed Seal Availability

Sensitivity Test 2. Sensitivity of node D1:Overall Population Outcome to Listing Factor nodes

Node	Mutual Info	Node title
F2	0.60174	Factor A: Habitat Threats
A1	0.06391	Factor B. Direct Mortalities
A6	0.03659	Factor E. Other factors (natural or man-made)
A4	0.01123	Factor C. Disease, predation

Sensitivity Test 3. Sensitivity of node D1:Overall Population Outcome to intermediate nodes

This does NOT includes the Listing Factor nodes included in Sensitivity Test 2, above.

Node	Mutual Info	Node title
L2	0.57024	Vital Rates
L1	0.53323	Adult Female Survival
L	0.53295	Juvenile Survival
K	0.51522	Adult Body Condition
V1	0.42691	Cub production per event
U	0.23368	Reproduction
D	0.18791	Change in Foraging Habitat Distribution
A	0.02592	Foraging habitat value
C1	0.02114	Human disturbance
G	0.00000	Relocation Possible
H	0.00000	Crowding Tolerance
C2	0.00000	Pollution

Sensitivity Test 4. Sensitivity of node D1:Overall Population Outcome to selected intermediate nodes

This includes all (6) nodes that are two links distant from the outcome node.

Node	Mutual Info	Node title
F2	0.60174	Factor A: Habitat Threats
L2	0.57024	Vital Rates
A1	0.06391	Factor B. Direct Mortalities
G	0.00000	Relocation Possible
A6	0.03659	Factor E. Other factors (natural or man-made)
A4	0.01123	Factor C. Disease, predation

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SENSITIVITY GROUP 2: SENSITIVITY OF SUBMODELS

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Sensitivity Test 5. Sensitivity of node A4:Factor C. Disease, predation

Node	Mutual Info	Node title
T	0.39016	Parasites & Disease
T2	0.06593	Predation

Sensitivity Test 6. Sensitivity of node C2: Pollution

Node	Mutual Info	Node title
R4	0.69005	Hydrocarbons/Oil Spill
T1	0.13542	Contaminants

Sensitivity Test 7. Sensitivity of node C1:Human disturbance

Node	Mutual Info	Node title
B1	0.45796	Bear-human interactions
R1	0.12450	Oil & Gas Activity
J	0.08941	Shipping
J1	0.01729	Tourism

Sensitivity Test 8. Sensitivity of node A:Foraging habitat value

Node	Mutual Info	Node title
S1	0.63429	Foraging habitat character
F	0.00000	Alternate Regions Available
R3	0.00000	Alternate Prey Availability
R2	0.00000	Relative Ringed Seal Availability

Sensitivity Test 9. Sensitivity of node D:Change in Foraging Habitat Distribution

Node	Mutual Info	Node title
M	0.33239	Geographic Area
C	0.32674	Foraging Habitat Absence Change
N	0.06131	Shelf Distance Change (km)

Sensitivity Test 10. Sensitivity of node L2:Vital Rates

Node	Mutual Info	Node title
L1	1.09792	Adult Female Survival
L	1.09537	Juvenile Survival
F2	0.99215	Factor A: Habitat Threats
K	0.97559	Adult Body Condition
V1	0.69213	Cub production per event
U	0.36497	Reproduction
M	0.04728	Geographic Area
N	0.01955	Shelf Distance Change (km)

Appendix 2. Documentation of the Bayesian network polar bear population stressor model

This appendix documents the structure of the Bayesian network (BN) population stressor model. We used the BN modeling shell Netica® (Norsys, Inc.) to create a model that represents potential influences on distribution response, numerical response, and overall population response of polar bears under multiple stressors, which include anthropogenic stressors, natural disturbances, and other key environmental correlates to polar bear population amount and distribution.

The BN population stressor model was created to represent the knowledge and judgment of one polar bear biologist (S. Amstrup) with guidance from an ecologist modeler (B. Marcot). See the text for a brief explanations of Bayesian modeling and statistics. The general underlying influence diagram for the BN model is shown in Figure 4, and the full model is in Figure 5. A BN model consists of a series of variables represented as "nodes" (boxes in Fig. 5) that interact through links (arrows in Fig. 5). Nodes that have no incoming arrows are "input nodes" (the yellow boxes in Fig. 5, e.g., node T Parasites & Disease). Nodes with both incoming and outgoing arrows are summary nodes (or latent variables, e.g., node L2 Vital Rates). In our model, we also specified four of the summary nodes as listing factors used by USDI Fish and Wildlife Service (S. Morey, pers. comm.). Nodes with incoming arrows but no outgoing arrows are outcome nodes (node D1 Overall Population Outcome).

Each node in this model consists of a short node name (e.g., node D1), a longer node title (e.g., Overall Population Outcome), a set of states (e.g, larger, same as now, smaller, rare, and extinct), and an underlying probability table. The probability tables consist of unconditional (or prior) probabilities in the input nodes, or conditional probabilities in all other nodes, the latter representing probabilities of each state as a function of (conditional upon) the states of all nodes that directly influence it.

The following table presents a complete list of all nodes in the model with their short code letter names, their fuller titles, a description, their states, and the group (Node Set, in Netica parlance) to which it belongs (input nodes, output node, summary node, or summary listing factor node).

Node name	Node title	Node description	States
Input nodes			
T	Parasites & Disease	As the climate warms, regions of the arctic are hospitable to parasites and disease agents which formerly didn't survive there. Polar bears have always been free of most disease and parasite agents. *Trichinella* is one notable exception, but even rabies, common in the Arctic has had no significance to polar bears. Changes in other species disease vulnerability suggest that similar changes could occur in polar bears so that they could move from a position where parasites and disease are not influential on a population level to where they are influential.	influential not
T2	Predation	Predation on polar bears by other species is very uncommon partly because bears spend almost all of their time on the ice. With more time on land, polar bears, especially young will be subject to increased levels of predation from wolves, and perhaps grizzly bears. This will vary by region as some regions where polar bears occur have few other predators. Intraspecific predation is one behavior which is known to occur in bears. It has rarely been observed in polar bears and historically is not thought to have been influential. Recent observations of predation on other bears by large males, in regions where it has not been observed before, are consistent with the hypothesis that this sort of behavior may increase in frequency if polar bears are nutritionally stressed. At present, intraspecific predation is not thought to be influential at the population level anywhere in the polar bear range. It appears, however, that its frequency may be on the increase. At some point, it therefore could become influential. At very low population levels, even a miner increase in predation could be influential.	influential not
E	Intentional Takes	This node represents direct mortalities including hunting, and collection for zoos, and management actions. It also includes research deaths even though they are not intentional. These are mortality sources that are very much controllable by regulation.	increased same_as_now decreased
T1	Contaminants	Increased precipitation and glacial melt have recently resulted in greater influx of contaminants into the Arctic region from the interior of Eurasia via the larte. northward flowing rivers. Similarly, differing atmospheric circulation patterns have altered potential pathways for contaminants from lower latitudes. This node reflects the possible increase or decrease of contamination in the Arctic as a result of modified pathways. These contaminants can act to make habitat less suitable and directly affect things like survival and reproduction. The greatest likelihood seems to be that such contaminants will increase in Arctic regions (and indeed worldwide) as increasing numbers of chemicals are developed and as their persistence in the environment is belatedly determined. Some contaminants have been reduced and we have the ability to reduce others, but the record of reduction and the persistence of many of these chemicals in the environment suggests the greatest likelihood is for elevated levels in the short to medium term with some probability of stability or even declines far in the future.	elevated same_as_now reduced
R4	Hydrocarbons / Oil Spill	This refers to the release of oil or oil related products into polar bear habitat. Such action would result in direct mortality of bears direct mortality of prey, and could result in displacement of bears from areas they formerly occupied. Hence, it has ramifications for both habitat quality and population dynamics directly. Hydrocarbon exploration and development are expanding and proposed to expand further in the Arctic. Greater levels of such activity are most likely to increase the probability of oil spills. Also, increased shipping will result in higher levels of hydrocarbon release into Arctic waters.	increased_occurrence same_as_now decreased_occurrence
J1	Tourism	As sea ice extent declines spatially and temporally access and opportunities for Arctic Tourism also will increase. Increased tourism could lead to direct disturbances of polar bears as well as to increased levels of contamination. Here, we address only the physical presence of more tourism and the conveyances used by tourists (vessels, land vehicles, aircraft). The greatest likelihood seems to be that tourism will increase. It could decline, however, if governments take actions to reduce interactions with increasingly stressed polar bears. However, as tourism currently accounts for essentially no limitation to polar bears this effect only comes into play when it is noted to increase.	increased same_as_now decreased

Node name	Node title	Node description	States
		I believe that tourism will increase in all areas of the Arctic until such time as fuel becomes too expensive for people to venture to such remote areas or in the polar basin divergent unit, when it is essentially devoid of ice, it may not attract many tourists and such activity may surge and then decline in that region. The arctic areas with more interesting coastlines etc., however will probably see nothing but increases in tourism. Contamination that may accompany such activities, and biological effects from introduced organisms that may compete with residents of the food web or cause disease are covered under the nodes for contamination and parasites and disease.	
B1	Bear-human interactions	This includes non-lethal takes which may increase as a result of increased human-bear interactions due to food stressed bears more frequently entering Arctic communities. Such takes can displace bears from their preferred locations and reduce habitat quality. This is separate from the similar interactions that may occur around oil and gas or other industrial sites which also can displace bears and lower habitat quality. These interactions also, however, can result in deaths as when problem bears are shot in defense of life and property So, this node includes a component of both habitat quality and direct mortality. I believe that bear-human interactions will increase until such time areas are devoid of bears or climate cools again and ice returns.	increased same_as_now decreased
R1	Oil & Gas Activity	This refers to the spatial effects of oil and gas activity. It refers to activities and infrastructure which may physically displace bears from habitat that was formally available to them. It also, can result in direct killings of bears which become a persistent safety problem around industrial facilities. Oil companies etc. have great resources to prevent these events from leading to mortalities, but such mortalities cannot be totally avoided and are likely to increase as habitat base shrinks. I think oil and gas activity will increase in the polar basin region through mid century and then decline because resources will have been tapped. We may see some increase in exploration and development in the Archipelago however, as it becomes increasingly accessible.	increase no_change decrease
J	Shipping	As sea ice extent declines spatially and temporally it is predicted that shipping in Arctic regions will increase. Increased shipping could lead to direct disturbances of polar bears as well as to increased levels of contamination. Here, we address only the physical presence of more vessel traffic. Contamination (bilge oil etc.), and biological effects from introduced organisms that may compete with residents of the food web or cause disease are covered under the nodes for contamination and parasites and disease. We allow only two states here: increased and same as now, because we can think of no reason why shipping will decrease in the foreseeable future. Even if international shipping does not increase, local shipping will because barges and vessels are more efficient ways to move fuel and freight into remote Arctic locations than aircraft.	increased same_as_now
F	Alternate Regions Available	Are there geographic regions to which bears from the subject region may effectively be able to relocate. This ability is contingent on other regions with suitable habitats being contiguous with regions where habitat quantity or quality have degraded to the point they won't support polar bears on a seasonal or annual basis. For example, if the sea ice is deteriorating throughout the polar basin including the Beaufort Sea and the last vestiges of ice are along the Alaskan Coast, there may no where else to go if the ice deteriorates to an unsatisfactory state. If, however, the ice retreates to the northeast as its extent reduces, bears remaining on the ice may have access to suitable habitats in the archipelago or in NE Greenland. I believe that bears in the seasonal ice region and in the polar basin will be able to collapse into the archipelago. Ice patterns suggest that the remaining ice in the arctic is likely to converge on the archipelage rather than form disjunct chunks of ice (although some GCMs do predict the latter, this is contrary to the historical record and the paleo record). Yes = other suitable areas are contiguous No = other suitable regions are not contiguous	Yes No

Node name	Node title	Node description	States
R2	Relative Ringed Seal Availability	This node expresses changes in prey availability that are likely to occur as sea ice cover declines and its character changes. This node specifically includes only the possibility that ringed seals, the mainstay of polar bears over most of their range might change in abundance and availability. This is specific to the amount of remaining ice. That is, as sea ice declines in coverage (which is the only way it seems possible for it to go) will the remaining habitat be more productive. Availability here refers to the combined effects of abundance and accessibility recognizing that seals may occupy areas that make them less available to polar bears even if the seals are still relatively abundant. Examples of this are the recent observations of failed bear attempts to dig through solid ice (a result of the thinner ice that deforms and rafts more easily) that predominates now, and the fact that seals may simply stay in open water all summer and not be available to bears even if the seal numbers are stable. My opinion is that only in the northern part of the ice convergent zone of the polar basin and in portions of the archipelago are conditions to improve for ringed seal availability. And, there, such improvements are likely to be transient perhaps through mid century. increase = greater abundance or availability of ringed seals same as now decrease = less abundance or availability	increase same_as_now decrease
R3	Alternate Prey Availability	This node expresses changes in prey availability that are likely to occur as sea ice cover declines and its character changes. This is largely expert opinion because there is little to go on to suggest prey base change possibilities in the future. With very different ice and other ecological differences that may accompany global warming things could occur which are totally unforeseen. Today's experience, however, suggests that little in the way of significant alternate prey is likely to emerge to allow bears to replace traditional prey that may be greatly reduced in the future. Where alternate prey could become important is in the seasonal ice regions and the archipelago. Now, harp and hooded seals have become important to polar bears as they have moved farther north than historically. As the ice retreats into the archipelago it is reasonable to expect that these animals may penetrate deeper into the archipelago and provide at least a transient improvement in alternate prey. It is unclear, however, that such changes could persist as bears prey on these seals which are forced onto smaller an smaller areas of ice. So, I project only transient improvements followed by decline. This node specifically addresses the possibility that alternate prey either marine or terrestrial might change in a way that would allow polar bears to take advantage of it. increase = greater availability of alternate prey same as now decrease = less opportunity for access to prey items other than ringed seals	increase same_as_now decrease
S1	Foraging habitat character	This node expresses a subjective assessment of the quality of sea ice for foraging by polar bears. Recent observations of the changes in sea ice character in the southern Beaufort Sea suggest that the later freeze up warmer winters, and earlier ice retreat in summer have resulted in thinner ice that more easily deforms and more frequently rafts over itself. These changes have reduced the quality of ice as a denning substrate, and may have reduced its quality as a foraging substrate since the extensive ice deformation can result in ice covered refugia for ringed seals which are less likely for polar bears to get into. Also, it can result in very rough sharp pressure ridges that are hugely expansive compared to earlier years. This rough ice may also provide refuge for seals, and it also is surely difficult for polar bear coys to negotiate as they attempt to move out onto the ice after den emergence in spring. More optimal ice is somewhat heavier not as rough, with pressure ridges composed of larger ice blocks. However, it can go the other way now. Very heavy stable ice in the Beaufort Sea in the past may have been limiting polar bears. This is also probably currently true in portions of the Canadian Archipelago and in the northern part of the Ice convergent zone of the polar basin. So, in those areas, I expect that ice quality will at first improve with global warming and then decline. Because my only sense of this ice quality is in the polar basin, I am leaving all priors uniform for the other ice	more_optimal same_as_now less_optimal

Node name	Node title	Node description	States
		regions.	
C	Foraging Habitat Absence Change	This node expresses the length in months of ice absence from the continental shelf regions currently preferred by polar bears. It correspondes to the value "proportional ice free months" from Dave Douglas' calculations based on GCMs. This is the number of months during which the continental shelf was ice free where ice free is defined as fewer than 50% of the pixels over the shelf having less than 50% ice cover. We express this as a change from now. so the figures in this node represent the difference in months between the forecasted number of ice free months for three future time periods and the number of ice free months for the present which is defined as the GCM model outputs for the period 2001-2010. The bears in some regions already experience protracted ice free periods. In other regions they don't. The impact of the length of the ice free period is dependent mainly upon the productivity of the environment, and has a different impact in the Beaufort Sea for example than it does in the currently seasonal ice environments which are, for the most part, very productive. For example, in the archipelago and PB convergence regions the mean time expressed in teh table must be interpreted with regard to the fact that in large parts of these areas even at a mean 1-3 months of increased absence, actual absence in some parts of these regions would still be 0. An absence difference of GT 3 months means a mean absence of 7 or 8 months in the PB divergent zone, and 8 9 or 10 months in the seasonal ice zone, but only 3 + months in portions of the archipelago or the PB convergence region.	-1 to 0 0 to 1 1 to 3 >=3
B	Foraging Habitat Quantity Change	This node expresses the proportional change in the area of polar bear habitat over time. Polar bear habitat is expressed as the number of square km months of optimal RSF habitat in the two polar basin geographic units, and as square km months of ice over continental shelf in the other regions. Because the other regions are almost entirely shallow water areas, the habitat in those areas boils down to essentially the ice extent months over each region. We further express this as the percent change in quantity of these ice habitats, from the baseline now which is defined as the period 1996-2006. Interpreting the percent difference must take into account that a given percent change in the archipelago or the PB convergent region is a very different thing than it might be in the other two units. The absolute change in the archipelago, for example may be very small, but because it is measured from essentially 0, it may look like a great % . These measurements are derived from the satellite record for the observational period and from the GCM outputs of sea ice for future periods.	0 to 20 -20 to 0 -40 to -20 < -40
N	Shelf Distance Change (km)	This node expresses the distance that the ice retreats from traditional autumn/winter foraging areas which are over the continental shelves and other shallow water areas within the polar basin. It is calculated by extracting the largest contiguous chunk of ice whose pixels have >50% concentration and determining the mean of the measured distances between all cells in the subpopulation unit and the nearest point within that chunk of ice. It is expressed as the difference between this mean distance calculated for the period 1996-2006 and the same mean distance calculated for the other time periods of interest. These distances are derived from the satellite record for the observational period and from the GCM outputs of sea ice for future periods. Expressing this value as a change from the current time allows the model to show that conditions improve in a hind cast back to the period of 1985-1995. This measurement is available only from the polar basin management units because all other management units occur in areas that are essentially all shelf. Hence, the measurement of distance to shelf means nothing. How far has the ice retreated from shore areas where polar bears traditionally have foraged in autumn and winter. Can/will bears make the trip from remaining summer refugia to these areas. This node also could be expressed simply as accessible or inaccessible as in denning areas above. This may not apply to regions other than the polar basin, because we don't have reliable assessments of where the	-200 to 0 0 to 200 200 to 800 >= 800

Node name	Node title	Node description	States
		sea ice will be at maximum retreat. Need to look at this question more closely. NOTE that we need to revisit how these values are calculated because the July values put in don't really seem to reflect real distances in for example the Archipelago where the ice is not expected to be away from the shelf for a long time to come. NOTE also that this difference change means a very different think in the divergent unit than it does in teh convergent unit. The mean distance to the shelf in the archipelago unit at future times will incorporate regions where there is no ice retreat at all and some regions where the change may be quite great (like the northern Beaufort). The overall change in the unit will actually be much more modest than the mean value suggests. In the divergent unit, however, a large mean distance means that the ice is uniformly a long way from the continental shelf.	
M	Geographic Area	Geographic region used for combining populations of polar bears.	Polar_Basin_Divergence Polar_Basin_Convergence Archipelago Seasonal_Ice
		Output Nodes \a	
D1	Overall Population Outcome	Composite influence of numerical response and distribution response.	larger same_as_now smaller rare extinct
C4	Numerical Response	This node represents the anticipated numerical response of polar bears based upon the sum total of the identified factors which are likely to have affected numbers of polar bears in any particular area.	increased_density same_as_now reduced_density rare absent
C3	Distribution Response	This is the sum total of ecological and human factors that predict the future distribution of polar bears. Reduced but Resident: habitat has changed in a way that would likely lead to a reduced spatial distribution (e.g. due to avoidance of a human development, or sea ice is still present in the area but in more limited quantity). Bears would still occur in the area, but their distribution would be more limited. Transient = habitat is seasonally limited or human activities have resulted in a situation where available ice is precluded from use on a seasonal basis.	same_as_now reduced_but_resident transient_visitors extirpated
		Summary Nodes	
C2	Pollution	This is the sum of pollution effects from hydrocarbon discharges directly into arctic waters and from other pollutants brought to the Arctic from other parts of the world. The FWS listing proposal included Pollution as one of the "other factors" along with direct human bear interactions that may displace bears or otherwise make habitats less satisfactory, I viewed the main effect of pollution as a potential effect on population dynamics. Clearly, severe pollution as in an oil spill for example, could make habitats unsatisfactory and result in direct displacement. The main effect, however, is likely to be how pollution affects immune systems, reproductive performance, and survival. Hence, I have included input from this node as well as from the human disturbance node into both the habitat and the abundance side of the network by including input from Factor E into both population effects and habitat effects.	reduced same_as_now elevated greatly_elevated
C1	Human disturbance	This node expresses the combination of the changes in "other" direct human disturbances to polar bears. This does not include changes in sea ice habitat. Nor does it include the contamination possibilities from hydrocarbon exploration. Those are covered elsewhere. It does cover the direct bear-human interactions that can occur in association with industrial development.	reduced same_as_now elevated greatly_elevated

Node name	Node title	Node description	States
H	Crowding Tolerance	The degree to which polar bears may tolerate increased densities that may result from migration of bears from presently occupied regions that become unsuitable to other regions already occupied by polar bears. In essence, this is the tolerance of bears to live in more crowded conditions than those at which they presently live. And, it is a function of food availability I believe that bears have a reasonable tolerance of crowding if food is abundant or if they are in good condition while waiting for sea ice to return etc. Examples of these situations include 1) portions of the high arctic like near resolute, where bear densities on the sea ice in spring are apparently much higher than they are in most of the polar basin, and 2) the high densities at which polar bears occur on land in Hudson Bay in summer when they are loafing and waiting for the sea ice to return. I assumed that crowding tolerance has little or no effect on outcome likelihoods until habitat quantity was reduced substantially requiring bears from one area to either perish or find some place else to go on at least a seasonal basis. Thereafter, if relocations of members of some subpopulations meant invading the areas occupied by other bears crowding tolerance entered an assessment of whether or not relocation was a practical solution.	none moderate high
G	Relocation Possible	Is it likely that polar bears displaced from one region could either seasonally or permanently relocate to another region in order to persist. This is a function of foraging effects (e.g. prey availability) in the alternative area (here I am specifically focusing on prey availability in the alternative area rather than the area from which the bears may have been displaced) crowding tolerance, and contiguity of habitats.	Yes No
A	Foraging habitat value	This node expresses the sum total of things which may work to alter the quality of habitats available to polar bears in the future. The idea here is that sea ice is retreating spatially and temporally, but is the ice that remains of comparable, better or worse quality as polar bear habitat. Our RSF values are projected into the future with the assumption that a piece of ice in 2090 that looks the same as piece of ice in 1985 has the same value to a polar bear. Perhaps because of responses we cannot foresee, it may be better seal habitat, or it may be habitat for an alternate prey. Conversely, it may be worse because of atmospheric and oceanic processes (e.g. the epontic community is less vibrant due to thinner ice which is not around for as long each year). Or it may be worse habitat because of oil and gas development, tourism, shipping etc.	better same_as_now worse
D	Change in Foraging Habitat Distribution	This node expresses the combination of the quantitative ways the retreat of sea ice may affect use of continental shelf habitats. Our analyses indicate, in addition to reductions of total ice (and RSF Optimum ice) extent (expressed under habitat quantity), we will see seasonal retreats of the sea ice away from coastal areas now preferred by polar bears, and these retreats are projected to progressively become longer. These changes will affect polar bears by reducing the total availability of ice substrate for bears. They also will make ice unavailable for extended periods in many regions bears now occur year round. This will result in the opportunity for seasonal occupancy but not year-round occupancy as they have had in the past. Note that in the PB Convergent unit because it includes the NB and QE and EG each of which has different starting points, the values in the CPT express kind of an average. Similarly, in the Seasonal region, there is a huge difference between HBay and Foxe Basin or BB. so, again the CPT values are a sort of an average, trying to reflect these differences. Ultimately, we need to subdivide these regions a bit more to really reflect what is going on. Also note that the "same as now" category doesn't really work very well for the seasonal ice environment where now is seasonal. The only way to go from here is to better than now or to sporadic. Having a step between now and sporadic is not useful. In fact, all of these categories need to be changed.	improved_availability same_as_now reduced_avail Gr_reduced_avail Unavailable
L2	Vital Rates	This expresses the combined effect of changes in survival of adult females and of young and reproductive patterns. The probabilities assigned each of the states reflects the relative importance to polar bear population dynamics of each of these vital rates to the growth of the population. This node does not reflect human influences on population growth such as hunting, or mortalities resulting from	improve same_as_now decline

Node name	Node title	Node description	States
		bear-human interactions. Those things, along with effects of parasites, contaminants, etc. are brought in as modifiers at the level of the next node.	
U	Reproduction	The sum of trends in numbers of cubs produced and the effect of retreating sea ice on the ability of females to reach traditional denning areas.	increased same_as_now decreased
V1	Cub production per event	This node describes the number of cubs produced per denning attempt.	Fewer_than_now same_as_now more_than_now
L	Juvenile Survival	Annual natural survival rate of cubs and yearlings. Note that this is conditional on survival of the mother. This is the survival rate for juveniles that would occur in absence of hunting or other anthropogenic factors. Those anthropogenic factors that would influence survival are included in node F.	increase no_change decrease
L1	Adult Female Survival	Annual natural survival rate of sexually mature females. This is the survival rate for adult females that would occur in absence of hunting or other anthropogenic factors. Those anthropogenic factors that would influence survival are included in node F.	increase no_change decrease
K	Adult Body Condition	Body mass index or other indicator of ability of bears to secure resources. Our analysis suggests body condition has been declining in the SBS and is inversely correlated with ice extent. Also recent analyses indicate that body condition is an important predictor of survival of polar bears in SHB.	increase same_as_now decrease
Summary Nodes – USFWS Listing Factors \b			
F2	Factor A: Habitat Threats	This node summarizes the combined information about changes in habitat quantity and quality. It approximately reflects factor A of the proposal to list polar bears as threatened.	improvement no_effect minor_restriction major_restriction
A1	Factor B. Overutilization	This node approximates the FWS listing Factor B. It includes the combination of hunting (harvest), take for scientific purposes, and take for zoos. It also includes mortalities from bear-human interactions etc. brought in from Factor E. These all are factors which serve to modify the population changes that would be brought about without the direct local interference of humans.	fewer same_as_now more
A4	Factor C. Disease, predation	This node expresses probability of changing vulnerability of polar bears to diseases and parasites, and to potential increases of intraspecific predation/cannibalism.	same_as_now worse
A6	Factor E. Other factors (natural or man-made)	This node approximately corresponds to Factor E of the listing proposal. It includes factors (other than the changes in sea ice quality and quantity) which may affect habitat suitability for polar bears. Also, its effects can be directly on population dynamics features. Hence, it applies directly to both the habitat and population sides of our network. Included here are effects of a variety of contaminants, including: petroleum hydrocarbons, persistent organic pollutants, and metals. Although we don't know much quantitatively about effects of these contaminants at the population level, we know qualitatively that effects on immune systems and steroid levels etc. will ultimately have such effects. We also know that oil spills will have immediate and dire effects. It also includes effects of human activities and developments which may directly affect habitat quality, including: shipping and transportation activities, habitat change, noise, spills, ballast discharge, and ecotourism. This includes disturbance but not direct killing of bears by humans as a result of DLP cases (direct killing is included under node A1). I viewed human disturbances as the most predictable in their negative effects until pollution levels reached their greatly elevated stage at which time, their import to future populations was judged to be great.	improvement no_effect minor_restriction major_restriction

Node name	Node title	Node description	States
Descriptive (Disconnected) Nodes \c			
Q	Time Period	The states for this node correspond to years -10 (historic), 0 (now), 45 (mid-century), 75 (late century), and 100 (end of century).	historic (1985-1995) now (1996-2006) mid-century (2045-2055) late century (2070-2080) end of century (2090-2099)
R	CGM run	The states for this node correspond to the data source (either "satellite" for year -10 and 0 runs) and GCN modeling scenario (minimum, ensemble mean, or maximum) basis for a given condition.	GCM_minimum Ensemble_mean GCM_maximum Satellite

\a Output nodes here include the Numerical Response and Distribution Response nodes that provide summary output conditions.

\b USDI Fish and Wildlife Service (USFWS) lists 5 Listing Factors. Listing factor D pertains to inadequacy of existing regulatory mechanisms, and was not included in the BN population stressor model because it does not correspond to any specific environmental stressor.

\c These two nodes are included in the model to help denote the basis for a given model run. They are not included as environmental stressors per se.

Appendix 3. Probability tables for each node in the Bayesian network model

Following are probability tables for each node in the BN model. (These were generated in the Netica software.) Not included here are all input nodes (yellow coded nodes in Fig. 5) because each of their prior probability tables was set to uniform distributions.

node H – "Crowding Tolerance"

Node R2 - Alternative prey availability	Node R3 - Relative ringed seal availability	Level of Crowding Tolerance		
		none	moderate	high
increase	increase	0.0	0.2	0.8
increase	same as now	0.0	0.4	0.6
increase	decrease	0.1	0.5	0.4
same as now	increase	0.0	0.4	0.6
same as now	same as now	0.1	0.8	0.1
same as now	decrease	0.3	0.6	0.1
decrease	increase	0.1	0.5	0.4
decrease	same as now	0.3	0.5	0.2
decrease	decrease	0.5	0.5	0.0

node G – "Relocation Possible"

Node F - Alternative regions available	Node H - Crowding tolerance	Possibilty of relocation	
		Yes	No
Yes	none	0.0	1.0
Yes	moderate	0.8	0.2
Yes	high	1.0	0.0
No	none	0.0	1.0
No	moderate	0.0	1.0
No	high	0.0	1.0

node A – "Foraging habitat value"

Node S1 - Foraging habitat character	Node G - Relocation possible	Value of foraging habitat		
		better	same as now	worse
more optimal	Yes	0.7	0.3	0.0
more optimal	No	0.2	0.6	0.2
same as now	Yes	0.1	0.8	0.1
same as now	No	0.0	0.8	0.2
less optimal	Yes	0.0	0.3	0.7
less optimal	No	0.0	0.0	1.0

node N – "Shelf Distance Change (km)"

Distance of shelf change			
-200 to 0	0 to 200	200 to 800	>= 800
0.25	0.25	0.25	0.25

node D – "Change in Foraging Habitat Distribution"

Node M - Geographic area	Node C - Foraging habitat absence change	Node N - Shelf distance change	Distribution of foraging habitat improved availab	same as now	reduced avail	Gr reduced avail	unavailable
Polar Basin Dive	-1 to 0	-200 to 0	1.0	0.0	0.0	0.0	0.0
Polar Basin Dive	-1 to 0	0 to 200	0.8	0.2	0.0	0.0	0.0
Polar Basin Dive	-1 to 0	200 to 800	0.2	0.6	0.2	0.0	0.0
Polar Basin Dive	-1 to 0	>= 800	0.0	0.4	0.6	0.0	0.0
Polar Basin Dive	0 to 1	-200 to 0	0.5	0.5	0.0	0.0	0.0
Polar Basin Dive	0 to 1	0 to 200	0.0	0.2	0.8	0.0	0.0
Polar Basin Dive	0 to 1	200 to 800	0.0	0.0	0.5	0.5	0.0
Polar Basin Dive	0 to 1	>= 800	0.0	0.0	0.25	0.5	0.25
Polar Basin Dive	1 to 3	-200 to 0	0.2	0.4	0.4	0.0	0.0
Polar Basin Dive	1 to 3	0 to 200	0.0	0.0	0.5	0.3	0.2
Polar Basin Dive	1 to 3	200 to 800	0.0	0.0	0.2	0.4	0.4
Polar Basin Dive	1 to 3	>= 800	0.0	0.0	0.0	0.2	0.8
Polar Basin Dive	>= 3	-200 to 0	0.0	0.3	0.5	0.2	0.0
Polar Basin Dive	>= 3	0 to 200	0.0	0.0	0.2	0.4	0.4
Polar Basin Dive	>= 3	200 to 800	0.0	0.0	0.0	0.1	0.9
Polar Basin Dive	>= 3	>= 800	0.0	0.0	0.0	0.0	1.0
Polar Basin Conv	-1 to 0	-200 to 0	1.0	0.0	0.0	0.0	0.0
Polar Basin Conv	-1 to 0	0 to 200	0.8	0.2	0.0	0.0	0.0
Polar Basin Conv	-1 to 0	200 to 800	0.6	0.4	0.0	0.0	0.0
Polar Basin Conv	-1 to 0	>= 800	0.4	0.6	0.0	0.0	0.0
Polar Basin Conv	0 to 1	-200 to 0	1.0	0.0	0.0	0.0	0.0
Polar Basin Conv	0 to 1	0 to 200	0.6	0.4	0.0	0.0	0.0
Polar Basin Conv	0 to 1	200 to 800	0.2	0.4	0.4	0.0	0.0
Polar Basin Conv	0 to 1	>= 800	0.0	0.2	0.8	0.0	0.0
Polar Basin Conv	1 to 3	-200 to 0	0.6	0.4	0.0	0.0	0.0
Polar Basin Conv	1 to 3	0 to 200	0.1	0.5	0.4	0.0	0.0
Polar Basin Conv	1 to 3	200 to 800	0.0	0.3	0.7	0.0	0.0
Polar Basin Conv	1 to 3	>= 800	0.0	0.0	1.0	0.0	0.0
Polar Basin Conv	>= 3	-200 to 0	0.4	0.6	0.0	0.0	0.0
Polar Basin Conv	>= 3	0 to 200	0.1	0.3	0.5	0.1	0.0

Polar Basin Conv	>= 3	200 to 800	0.0	0.2	0.6	0.2	0.0
Polar Basin Conv	>= 3	>= 800	0.0	0.0	0.7	0.3	0.0
Archipelago	-1 to 0	-200 to 0	0.0	1.0	0.0	0.0	0.0
Archipelago	-1 to 0	0 to 200	0.0	1.0	0.0	0.0	0.0
Archipelago	-1 to 0	200 to 800	0.0	1.0	0.0	0.0	0.0
Archipelago	-1 to 0	>= 800	0.0	1.0	0.0	0.0	0.0
Archipelago	0 to 1	-200 to 0	0.6	0.4	0.0	0.0	0.0
Archipelago	0 to 1	0 to 200	0.6	0.4	0.0	0.0	0.0
Archipelago	0 to 1	200 to 800	0.6	0.4	0.0	0.0	0.0
Archipelago	0 to 1	>= 800	0.6	0.4	0.0	0.0	0.0
Archipelago	1 to 3	-200 to 0	0.4	0.6	0.0	0.0	0.0
Archipelago	1 to 3	0 to 200	0.4	0.6	0.0	0.0	0.0
Archipelago	1 to 3	200 to 800	0.4	0.6	0.0	0.0	0.0
Archipelago	1 to 3	>= 800	0.4	0.6	0.0	0.0	0.0
Archipelago	>= 3	-200 to 0	0.0	0.6	0.4	0.0	0.0
Archipelago	>= 3	0 to 200	0.0	0.6	0.4	0.0	0.0
Archipelago	>= 3	200 to 800	0.0	0.6	0.4	0.0	0.0
Archipelago	>= 3	>= 800	0.0	0.6	0.4	0.0	0.0
Seasonal Ice	-1 to 0	-200 to 0	0.5	0.5	0.0	0.0	0.0
Seasonal Ice	-1 to 0	0 to 200	0.5	0.5	0.0	0.0	0.0
Seasonal Ice	-1 to 0	200 to 800	0.5	0.5	0.0	0.0	0.0
Seasonal Ice	-1 to 0	>= 800	0.5	0.5	0.0	0.0	0.0
Seasonal Ice	0 to 1	-200 to 0	0.0	0.2	0.6	0.2	0.0
Seasonal Ice	0 to 1	0 to 200	0.0	0.2	0.6	0.2	0.0
Seasonal Ice	0 to 1	200 to 800	0.0	0.2	0.6	0.2	0.0
Seasonal Ice	0 to 1	>= 800	0.0	0.2	0.6	0.2	0.0
Seasonal Ice	1 to 3	-200 to 0	0.0	0.0	0.2	0.4	0.4
Seasonal Ice	1 to 3	0 to 200	0.0	0.0	0.2	0.4	0.4
Seasonal Ice	1 to 3	200 to 800	0.0	0.0	0.2	0.4	0.4
Seasonal Ice	1 to 3	>= 800	0.0	0.0	0.2	0.4	0.4
Seasonal Ice	>= 3	-200 to 0	0.0	0.0	0.0	0.1	0.9
Seasonal Ice	>= 3	0 to 200	0.0	0.0	0.0	0.1	0.9
Seasonal Ice	>= 3	200 to 800	0.0	0.0	0.0	0.1	0.9
Seasonal Ice	>= 3	>= 800	0.0	0.0	0.0	0.1	0.9

node F2 – "Factor A: Habitat Threats"

Node B - Foraging habitat quantity change	Node D - Change in foraging habitat distribution	Node A - Foraging habitat value	Level of habitat threat			
			improvement	no effect	minor restriction	major restriction
0 to 20	improved availab	better	1.0	0.0	0.0	0.0
0 to 20	improved availab	same as now	1.0	0.0	0.0	0.0
0 to 20	improved availab	worse	0.8	0.2	0.0	0.0
0 to 20	same as now	better	1.0	0.0	0.0	0.0
0 to 20	same as now	same as now	0.8	0.2	0.0	0.0
0 to 20	same as now	worse	0.3	0.5	0.2	0.0
0 to 20	reduced avail	better	0.4	0.4	0.2	0.0
0 to 20	reduced avail	same as now	0.2	0.6	0.2	0.0
0 to 20	reduced avail	worse	0.0	0.2	0.6	0.2
0 to 20	Gr reduced avail	better	0.0	0.2	0.4	0.4
0 to 20	Gr reduced avail	same as now	0.0	0.0	0.4	0.6
0 to 20	Gr reduced avail	worse	0.0	0.0	0.2	0.8
0 to 20	unavailable	better	0.0	0.0	0.0	1.0
0 to 20	unavailable	same as now	0.0	0.0	0.0	1.0
0 to 20	unavailable	worse	0.0	0.0	0.0	1.0
-20 to 0	improved availab	better	0.8	0.2	0.0	0.0
-20 to 0	improved availab	same as now	0.2	0.6	0.2	0.0
-20 to 0	improved availab	worse	0.2	0.4	0.4	0.0
-20 to 0	same as now	better	0.2	0.6	0.2	0.0
-20 to 0	same as now	same as now	0.0	0.2	0.6	0.2
-20 to 0	same as now	worse	0.0	0.0	0.6	0.4
-20 to 0	reduced avail	better	0.1	0.5	0.2	0.2
-20 to 0	reduced avail	same as now	0.0	0.1	0.5	0.4
-20 to 0	reduced avail	worse	0.0	0.0	0.4	0.6
-20 to 0	Gr reduced avail	better	0.0	0.0	0.5	0.5
-20 to 0	Gr reduced avail	same as now	0.0	0.0	0.2	0.8
-20 to 0	Gr reduced avail	worse	0.0	0.0	0.0	1.0

-20 to 0	unavailable	better	0.0	0.0	0.0	1.0
-20 to 0	unavailable	same as now	0.0	0.0	0.0	1.0
-20 to 0	unavailable	worse	0.0	0.0	0.0	1.0
-40 to -20	improved availab	better	0.4	0.4	0.2	0.0
-40 to -20	improved availab	same as now	0.1	0.5	0.4	0.0
-40 to -20	improved availab	worse	0.0	0.3	0.5	0.2
-40 to -20	same as now	better	0.1	0.4	0.4	0.1
-40 to -20	same as now	same as now	0.0	0.1	0.4	0.5
-40 to -20	same as now	worse	0.0	0.0	0.4	0.6
-40 to -20	reduced avail	better	0.0	0.1	0.6	0.3
-40 to -20	reduced avail	same as now	0.0	0.0	0.5	0.5
-40 to -20	reduced avail	worse	0.0	0.0	0.2	0.8
-40 to -20	Gr reduced avail	better	0.0	0.0	0.3	0.7
-40 to -20	Gr reduced avail	same as now	0.0	0.0	0.0	1.0
-40 to -20	Gr reduced avail	worse	0.0	0.0	0.0	1.0
-40 to -20	unavailable	better	0.0	0.0	0.0	1.0
-40 to -20	unavailable	same as now	0.0	0.0	0.0	1.0
-40 to -20	unavailable	worse	0.0	0.0	0.0	1.0
< -40	improved availab	better	0.2	0.6	0.2	0.0
< -40	improved availab	same as now	0.0	0.2	0.6	0.2
< -40	improved availab	worse	0.0	0.0	0.5	0.5
< -40	same as now	better	0.0	0.1	0.6	0.3
< -40	same as now	same as now	0.0	0.0	0.3	0.7
< -40	same as now	worse	0.0	0.0	0.2	0.8
< -40	reduced avail	better	0.0	0.1	0.2	0.7
< -40	reduced avail	same as now	0.0	0.0	0.1	0.9
< -40	reduced avail	worse	0.0	0.0	0.0	1.0
< -40	Gr reduced avail	better	0.0	0.0	0.0	1.0
< -40	Gr reduced avail	same as now	0.0	0.0	0.0	1.0
< -40	Gr reduced avail	worse	0.0	0.0	0.0	1.0
< -40	unavailable	better	0.0	0.0	0.0	1.0
< -40	unavailable	same as now	0.0	0.0	0.0	1.0
< -40	unavailable	worse	0.0	0.0	0.0	1.0

node C1 – "Human disturbance"

Node B1 - Bear-human interactions	Node J - Shipping	Node R1 - Oil & gas activity	Node J1- Tourism	Level of human disturbance reduced	same as now	elevated	greatly elevated
increased	increased	increase	increased	0.0	0.0	0.0	1.0
increased	increased	increase	same as now	0.0	0.0	0.0	1.0
increased	increased	increase	decreased	0.0	0.0	0.1	0.9
increased	increased	no change	increased	0.0	0.0	0.0	1.0
increased	increased	no change	same as now	0.0	0.0	0.1	0.9
increased	increased	no change	decreased	0.0	0.0	0.2	0.8
increased	increased	decrease	increased	0.0	0.0	0.3	0.7
increased	increased	decrease	same as now	0.0	0.0	0.6	0.4
increased	increased	decrease	decreased	0.0	0.0	0.5	0.5
increased	same as now	increase	increased	0.0	0.0	0.0	1.0
increased	same as now	increase	same as now	0.0	0.0	0.2	0.8
increased	same as now	increase	decreased	0.0	0.0	0.3	0.7
increased	same as now	no change	increased	0.0	0.0	0.5	0.5
increased	same as now	no change	same as now	0.0	0.0	0.7	0.3
increased	same as now	no change	decreased	0.0	0.2	0.6	0.2
increased	same as now	decrease	increased	0.0	0.0	0.7	0.3
increased	same as now	decrease	same as now	0.0	0.2	0.7	0.1
increased	same as now	decrease	decreased	0.0	0.4	0.6	0.0
same as now	increased	increase	increased	0.0	0.0	0.2	0.8
same as now	increased	increase	same as now	0.0	0.0	0.5	0.5
same as now	increased	increase	decreased	0.0	0.2	0.6	0.2
same as now	increased	no change	increased	0.0	0.2	0.8	0.0
same as now	increased	no change	same as now	0.0	0.3	0.7	0.0
same as now	increased	no change	decreased	0.0	0.5	0.5	0.0
same as now	increased	decrease	increased	0.0	0.3	0.7	0.0
same as now	increased	decrease	same as now	0.0	0.5	0.5	0.0

same as now	increased	decrease	decreased	0.0	0.6	0.4	0.0
same as now	same as now	increase	increased	0.0	0.2	0.8	0.0
same as now	same as now	increase	same as now	0.0	0.4	0.6	0.0
same as now	same as now	increase	decreased	0.0	0.5	0.5	0.0
same as now	same as now	no change	increased	0.0	0.8	0.2	0.0
same as now	same as now	no change	same as now	0.0	1.0	0.0	0.0
same as now	same as now	no change	decreased	0.1	0.9	0.0	0.0
same as now	same as now	decrease	increased	0.3	0.7	0.0	0.0
same as now	same as now	decrease	same as now	0.5	0.5	0.0	0.0
same as now	same as now	decrease	decreased	0.6	0.4	0.0	0.0
decreased	increased	increase	increased	0.0	0.0	0.6	0.4
decreased	increased	increase	same as now	0.0	0.2	0.6	0.2
decreased	increased	increase	decreased	0.0	0.3	0.7	0.0
decreased	increased	no change	increased	0.1	0.6	0.3	0.0
decreased	increased	no change	same as now	0.2	0.6	0.2	0.0
decreased	increased	no change	decreased	0.3	0.5	0.2	0.0
decreased	increased	decrease	increased	0.2	0.6	0.2	0.0
decreased	increased	decrease	same as now	0.3	0.7	0.0	0.0
decreased	increased	decrease	decreased	0.4	0.6	0.0	0.0
decreased	same as now	increase	increased	0.0	0.5	0.5	0.0
decreased	same as now	increase	same as now	0.2	0.6	0.2	0.0
decreased	same as now	increase	decreased	0.3	0.6	0.1	0.0
decreased	same as now	no change	increased	0.5	0.5	0.0	0.0
decreased	same as now	no change	same as now	0.7	0.3	0.0	0.0
decreased	same as now	no change	decreased	0.8	0.2	0.0	0.0
decreased	same as now	decrease	increased	0.9	0.1	0.0	0.0
decreased	same as now	decrease	same as now	1.0	0.0	0.0	0.0
decreased	same as now	decrease	decreased	1.0	0.0	0.0	0.0

node C2 – "Pollution"

Node R4 - Hydrocarbons / oil spill	Node T1 - Contaminants	Level of pollution reduced	same as now	elevated	greatly elevated
increased occurr	elevated	0.0	0.0	0.0	1.0
increased occurr	same as now	0.0	0.0	0.6	0.4
increased occurr	reduced	0.0	0.4	0.4	0.2
same as now	elevated	0.0	0.3	0.7	0.0
same as now	same as now	0.0	1.0	0.0	0.0
same as now	reduced	0.4	0.6	0.0	0.0
decreased occurr	elevated	0.3	0.5	0.2	0.0
decreased occurr	same as now	0.8	0.2	0.0	0.0
decreased occurr	reduced	1.0	0.0	0.0	0.0

node A6 – "Factor E. Other factors natural or man-made"

Node C1 - C1	Node C2 - C2	Level of other factors improvement	no effect	minor restrictio	major restrictio
reduced	reduced	1.0	0.0	0.0	0.0
reduced	same as now	1.0	0.0	0.0	0.0
reduced	elevated	0.3	0.4	0.3	0.0
reduced	greatly elevated	0.0	0.3	0.3	0.4
same as now	reduced	0.6	0.4	0.0	0.0
same as now	same as now	0.0	1.0	0.0	0.0
same as now	elevated	0.0	0.4	0.6	0.0
same as now	greatly elevated	0.0	0.2	0.2	0.6
elevated	reduced	0.0	0.2	0.5	0.3
elevated	same as now	0.0	0.0	0.5	0.5
elevated	elevated	0.0	0.0	0.4	0.6
elevated	greatly elevated	0.0	0.0	0.3	0.7
greatly elevated	reduced	0.0	0.0	0.3	0.7
greatly elevated	same as now	0.0	0.0	0.2	0.8
greatly elevated	elevated	0.0	0.0	0.1	0.9
greatly elevated	greatly elevated	0.0	0.0	0.0	1.0

node C3 – "Distribution Response"

Node F2 - Factor A. Habitat Threats	Node A6 - Factor E. Other factors (natural or man-made)	Node G - Relocation possible	Distribution response same as now	reduced but resi	transient visito	extirpated
improvement	improvement	Yes	1.0	0.0	0.0	0.0
improvement	improvement	No	1.0	0.0	0.0	0.0
improvement	no effect	Yes	1.0	0.0	0.0	0.0
improvement	no effect	No	1.0	0.0	0.0	0.0
improvement	minor restrictio	Yes	0.9	0.1	0.0	0.0
improvement	minor restrictio	No	0.9	0.1	0.0	0.0
improvement	major restrictio	Yes	0.8	0.1	0.1	0.0
improvement	major restrictio	No	0.8	0.2	0.0	0.0
no effect	improvement	Yes	1.0	0.0	0.0	0.0
no effect	improvement	No	1.0	0.0	0.0	0.0
no effect	no effect	Yes	1.0	0.0	0.0	0.0
no effect	no effect	No	1.0	0.0	0.0	0.0
no effect	minor restrictio	Yes	0.8	0.1	0.1	0.0
no effect	minor restrictio	No	0.8	0.2	0.0	0.0
no effect	major restrictio	Yes	0.5	0.2	0.3	0.0
no effect	major restrictio	No	0.5	0.5	0.0	0.0
minor restrictio	improvement	Yes	0.5	0.25	0.25	0.0
minor restrictio	improvement	No	0.5	0.5	0.0	0.0
minor restrictio	no effect	Yes	0.4	0.3	0.3	0.0
minor restrictio	no effect	No	0.4	0.6	0.0	0.0
minor restrictio	minor restrictio	Yes	0.3	0.3	0.4	0.0
minor restrictio	minor restrictio	No	0.3	0.6	0.0	0.1
minor restrictio	major restrictio	Yes	0.2	0.2	0.6	0.0
minor restrictio	major restrictio	No	0.2	0.5	0.0	0.3
major restrictio	improvement	Yes	0.0	0.3	0.35	0.35
major restrictio	improvement	No	0.0	0.3	0.0	0.7
major restrictio	no effect	Yes	0.0	0.2	0.4	0.4
major restrictio	no effect	No	0.0	0.2	0.0	0.8
major restrictio	minor restrictio	Yes	0.0	0.1	0.45	0.45
major restrictio	minor restrictio	No	0.0	0.1	0.0	0.9
major restrictio	major restrictio	Yes	0.0	0.0	0.3	0.7
major restrictio	major restrictio	No	0.0	0.0	0.0	1.0

node K – “Adult Body Condition”

Node F2 - Factor A. Habitat Threats	Quality of adult body condition increase	same as now	decrease
improvement	1.0	0.0	0.0
no effect	0.0	1.0	0.0
minor restrictio	0.0	0.5	0.5
major restrictio	0.0	0.0	1.0

node L1 – “Adult Female Survival”

Node K - Adult Body Condition	Node F2 - Factor A. Habitat Threats	Adult Female Survival increase	no change	decrease
increase	improvement	1.0	0.0	0.0
increase	no effect	0.8	0.2	0.0
increase	minor restrictio	0.1	0.6	0.3
increase	major restrictio	0.0	0.5	0.5
same as now	no effect	0.5	0.5	0.0
same as now	minor restrictio	0.0	0.6	0.4
same as now	major restrictio	0.0	0.3	0.7
decrease	improvement	0.0	0.4	0.6
decrease	no effect	0.0	0.2	0.8
decrease	minor restrictio	0.0	0.1	0.9
decrease	major restrictio	0.0	0.0	1.0

node L – "Juvenile Survival"

Node K - Adult Body Condition	Node L1 - Adult Female Survival	Juvenile Survival increase	no change	decrease
increase	increase	1.0	0.0	0.0
increase	no change	0.7	0.3	0.0
increase	decrease	0.0	0.4	0.6
same as now	increase	0.8	0.2	0.0
same as now	no change	0.0	1.0	0.0
same as now	decrease	0.0	0.2	0.8
decrease	increase	0.0	0.6	0.4
decrease	no change	0.0	0.3	0.7
decrease	decrease	0.0	0.0	1.0

node V1 – "Cub production per event"

Node F2 - Factor A. Habitat Threats	Cub Production per event Fewer than now	same as now	more than now
improvement	0.0	0.3	0.7
no effect	0.0	1.0	0.0
minor restrictio	0.6	0.4	0.0
major restrictio	1.0	0.0	0.0

node U – "Reproduction"

Node M - Geographic Area	Node V1 - Cub production per event	Node N - Shelf Distance Change (km)	Rate of reproduction increased	same as now	decreased
Polar Basin Dive	Fewer than now	-200 to 0	0.0	0.3	0.7
Polar Basin Dive	Fewer than now	0 to 200	0.0	0.2	0.8
Polar Basin Dive	Fewer than now	200 to 800	0.0	0.0	1.0
Polar Basin Dive	Fewer than now	>= 800	0.0	0.0	1.0
Polar Basin Dive	same as now	-200 to 0	0.7	0.3	0.0
Polar Basin Dive	same as now	0 to 200	0.0	1.0	0.0
Polar Basin Dive	same as now	200 to 800	0.0	0.3	0.7
Polar Basin Dive	same as now	>= 800	0.0	0.0	1.0
Polar Basin Dive	more than now	-200 to 0	1.0	0.0	0.0
Polar Basin Dive	more than now	0 to 200	0.5	0.5	0.0
Polar Basin Dive	more than now	200 to 800	0.0	0.5	0.5
Polar Basin Dive	more than now	>= 800	0.0	0.0	1.0
Polar Basin Conv	Fewer than now	-200 to 0	0.0	0.5	0.5
Polar Basin Conv	Fewer than now	0 to 200	0.0	0.4	0.6
Polar Basin Conv	Fewer than now	200 to 800	0.0	0.3	0.7
Polar Basin Conv	Fewer than now	>= 800	0.0	0.2	0.8
Polar Basin Conv	same as now	-200 to 0	1.0	0.0	0.0
Polar Basin Conv	same as now	0 to 200	0.5	0.5	0.0
Polar Basin Conv	same as now	200 to 800	0.2	0.6	0.2
Polar Basin Conv	same as now	>= 800	0.0	0.5	0.5
Polar Basin Conv	more than now	-200 to 0	1.0	0.0	0.0
Polar Basin Conv	more than now	0 to 200	0.8	0.2	0.0
Polar Basin Conv	more than now	200 to 800	0.4	0.4	0.2
Polar Basin Conv	more than now	>= 800	0.2	0.4	0.4
Archipelago	Fewer than now	-200 to 0	0.0	0.2	0.8
Archipelago	Fewer than now	0 to 200	0.0	0.2	0.8
Archipelago	Fewer than now	200 to 800	0.0	0.2	0.8
Archipelago	Fewer than now	>= 800	0.0	0.2	0.8
Archipelago	same as now	-200 to 0	0.2	0.6	0.2
Archipelago	same as now	0 to 200	0.2	0.6	0.2

Archipelago	same as now	200 to 800	0.2	0.6	0.2
Archipelago	same as now	>= 800	0.2	0.6	0.2
Archipelago	more than now	-200 to 0	0.8	0.2	0.0
Archipelago	more than now	0 to 200	0.8	0.2	0.0
Archipelago	more than now	200 to 800	0.8	0.2	0.0
Archipelago	more than now	>= 800	0.8	0.2	0.0
Seasonal Ice	Fewer than now	-200 to 0	0.0	0.2	0.8
Seasonal Ice	Fewer than now	0 to 200	0.0	0.2	0.8
Seasonal Ice	Fewer than now	200 to 800	0.0	0.2	0.8
Seasonal Ice	Fewer than now	>= 800	0.0	0.2	0.8
Seasonal Ice	same as now	-200 to 0	0.2	0.6	0.2
Seasonal Ice	same as now	0 to 200	0.2	0.6	0.2
Seasonal Ice	same as now	200 to 800	0.2	0.6	0.2
Seasonal Ice	same as now	>= 800	0.2	0.6	0.2
Seasonal Ice	more than now	-200 to 0	0.8	0.2	0.0
Seasonal Ice	more than now	0 to 200	0.8	0.2	0.0
Seasonal Ice	more than now	200 to 800	0.8	0.2	0.0
Seasonal Ice	more than now	>= 800	0.8	0.2	0.0

node L2 – "Vital Rates"

Node L1 - Adult Female Surival	Node L - Juvenile Survival	Node U - Reproduction	Vital Rates improve	same as now	decline
increase	increase	increased	1.0	0.0	0.0
increase	increase	same as now	1.0	0.0	0.0
increase	increase	decreased	0.6	0.4	0.0
increase	no change	increased	0.9	0.1	0.0
increase	no change	same as now	0.8	0.2	0.0
increase	no change	decreased	0.7	0.2	0.1
increase	decrease	increased	0.3	0.5	0.2
increase	decrease	same as now	0.2	0.5	0.3
increase	decrease	decreased	0.0	0.4	0.6
no change	increase	increased	0.7	0.3	0.0
no change	increase	same as now	0.6	0.4	0.0
no change	increase	decreased	0.2	0.5	0.3
no change	no change	increased	0.2	0.8	0.0
no change	no change	same as now	0.0	1.0	0.0
no change	no change	decreased	0.0	0.8	0.2
no change	decrease	increased	0.0	0.6	0.4
no change	decrease	same as now	0.0	0.5	0.5
no change	decrease	decreased	0.0	0.3	0.7
decrease	increase	increased	0.2	0.4	0.4
decrease	increase	same as now	0.0	0.6	0.4
decrease	increase	decreased	0.0	0.5	0.5
decrease	no change	increased	0.1	0.5	0.4
decrease	no change	same as now	0.0	0.4	0.6
decrease	no change	decreased	0.0	0.3	0.7
decrease	decrease	increased	0.0	0.2	0.8
decrease	decrease	same as now	0.0	0.0	1.0
decrease	decrease	decreased	0.0	0.0	1.0

node A1 – "Factor B. Overutilization"

Node E - Intentional Takes	Node A6 - Factor E. Other factors (natural or man-made)	Level of Overutilization fewer	same as now	more
increased	improvement	0.0	0.4	0.6
increased	no effect	0.0	0.0	1.0
increased	minor restrictio	0.0	0.0	1.0
increased	major restrictio	0.0	0.0	1.0
same as now	improvement	1.0	0.0	0.0
same as now	no effect	0.0	1.0	0.0
same as now	minor restrictio	0.0	0.6	0.4
same as now	major restrictio	0.0	0.3	0.7
decreased	improvement	1.0	0.0	0.0
decreased	no effect	1.0	0.0	0.0
decreased	minor restrictio	0.0	0.8	0.2
decreased	major restrictio	0.0	0.6	0.4

node A4 – "Factor C. Disease, predation"

Node T - Parasites & Disease	Node T2 - Predation	Level of disease, predation same as now	worse
influential	influential	0.0	1.0
influential	not	0.3	0.7
not	influential	0.7	0.3
not	not	1.0	0.0

node C4 – "Numerical Response"

Node L2 - Vital Rates	Node A1 - Factor B. Overutilization	Node A4 - Factor C. Disease, Predation	Numerical Response increased densit	same as now	reduced density	rare	absent
improve	fewer	same as now	1.0	0.0	0.0	0.0	0.0
improve	fewer	worse	0.5	0.25	0.25	0.0	0.0
improve	same as now	same as now	0.8	0.2	0.0	0.0	0.0
improve	same as now	worse	0.5	0.25	0.25	0.0	0.0
improve	more	same as now	0.3	0.35	0.35	0.0	0.0
improve	more	worse	0.1	0.4	0.5	0.0	0.0
same as now	fewer	same as now	0.2	0.8	0.0	0.0	0.0
same as now	fewer	worse	0.0	0.8	0.2	0.0	0.0
same as now	same as now	same as now	0.0	1.0	0.0	0.0	0.0
same as now	same as now	worse	0.0	0.3	0.7	0.0	0.0
same as now	more	same as now	0.0	0.2	0.8	0.0	0.0
same as now	more	worse	0.0	0.0	1.0	0.0	0.0
decline	fewer	same as now	0.0	0.5	0.5	0.0	0.0
decline	fewer	worse	0.0	0.3	0.7	0.0	0.0
decline	same as now	same as now	0.0	0.0	1.0	0.0	0.0
decline	same as now	worse	0.0	0.0	0.75	0.25	0.0
decline	more	same as now	0.0	0.0	0.4	0.4	0.2
decline	more	worse	0.0	0.0	0.2	0.4	0.4

node D1 – "overall population outcome"

Node C4 -	Node C3 -	Overall population outcome				
			same			
Numerical response	Distribution response	larger	as now	smaller	rare	extinct
increased densit	same as now	1.0	0.0	0.0	0.0	0.0
increased densit	reduced but resi	0.3	0.5	0.2	0.0	0.0
increased densit	transient visito	0.1	0.3	0.3	0.3	0.0
increased densit	extirpated	0.0	0.0	0.0	0.0	1.0
same as now	same as now	0.0	1.0	0.0	0.0	0.0
same as now	reduced but resi	0.0	0.3	0.7	0.0	0.0
same as now	transient visito	0.0	0.0	0.6	0.4	0.0
same as now	extirpated	0.0	0.0	0.0	0.0	1.0
reduced density	same as now	0.0	0.0	1.0	0.0	0.0
reduced density	reduced but resi	0.0	0.0	0.7	0.3	0.0
reduced density	transient visito	0.0	0.0	0.3	0.7	0.0
reduced density	extirpated	0.0	0.0	0.0	0.0	1.0
rare	same as now	0.0	0.0	0.0	1.0	0.0
rare	reduced but resi	0.0	0.0	0.0	0.8	0.2
rare	transient visito	0.0	0.0	0.0	0.7	0.3
rare	extirpated	0.0	0.0	0.0	0.0	1.0
absent	same as now	0.0	0.0	0.0	0.0	1.0
absent	reduced but resi	0.0	0.0	0.0	0.0	1.0
absent	transient visito	0.0	0.0	0.0	0.0	1.0
absent	extirpated	0.0	0.0	0.0	0.0	1.0

OPENING STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM THE STATE OF WYOMING

Senator BARRASSO. Thank you, Madam Chairman. I appreciate the opportunity to be here today and I appreciate the witnesses coming to testify.

I am just going to be very brief, if I could. It is just that when we last met before Christmas for the markup of the Lieberman-Warner bill in that long, marathon session, the final amendment, and I think they played that on C-SPAN all over the Christmas holidays. One night I went to bed and it was on and I woke up and the Committee meeting was still on C-SPAN.

[Laughter.]

Senator BARRASSO. It was something.

The final amendment that I offered, and we didn't get into a discussion, had to do with if Lieberman-Warner would be tied to the Endangered Species Act. I was assured that that was nowhere the intention, I believed that. Then I saw an article in the Baltimore Sun by the staff attorney at the Center for Biological Diversity. And she writes: "Once protection for the polar bear is finalized, Federal agencies and other large greenhouse gas emitters will be required by law to ensure that the emissions do not jeopardize the species. And the only way to avoid jeopardizing the polar bear is to reduce emissions."

So I would ask if I could make this article from the Baltimore Sun a part of the record, and I look forward to the discussion. Thank you.

[The referenced material was not submitted at time of print.]

Senator BOXER. Sure, and Senator, I just would point out to you that that is exactly what the ESA would require, it has nothing to do with any other law that we would pass. Unless we weaken the ESA, that may well be one of the things that is required. But it has nothing to do with Lieberman-Warner.

Senator Lieberman, I just wanted to point out that you do head the subcommittee that has within its jurisdiction the protection of wildlife. You have already held hearings on this, but I am just thrilled to have you here today.

OPENING STATEMENT OF HON. JOSEPH LIEBERMAN, U.S. SENATOR FROM THE STATE OF CONNECTICUT

Senator LIEBERMAN. Thanks, Madam Chairman.

Correct, in fact, that marathon that Senator Barrasso, at least in the C-SPAN version, slept through, he was wide awake when it actually happened, was preceded in the process that led to the adoption of the Climate Security Act in December and reporting by a majority of members of Committee to the floor actually began at a hearing almost a year ago to this day that Senator Warner and I convened in our subcommittee on the impacts of global warming on wildlife.

In that hearing, we heard of the ways in which unchecked global warming is already harming, and of course in the absence of further action, will increasingly harm species and entire ecosystems that are integral to our way of life and the well-being of human societies around the world. And of course, these species and ecosystems themselves have an inherent worth, in my belief structure, as part of God's creation, so that the impact on the well-being of human societies is important. But it is important to remember that these species have value within themselves. If I might just go on a moment, inspired, which is to say that I was raised in a tradition that reminded us that in the Bible, in Genesis, God says to Adam and Eve in the garden of Eden, from which we were unfortunately banned, that they have a responsibility to both work, which is to say enjoy, reap the benefits of, but also to guard and protect the garden and all that is in it, the implication being for future generations.

We hard in that hearing nearly a year ago quite a remarkable accumulation of testimony. In that hearing, the Fish and Wildlife Service Director, Mr. Hall, who we are privileged to have with us today, identified a warming climate and the resulting melting of sea ice as the primary reason that polar bears were threatened as a species. So we have both the indication of a threat to the species, but also if you will, the polar bear may be to global warming what the canary in the coal mine has been to danger for coal miners in the mine.

I would say parenthetically that we also had riveting testimony that day from a trout fisherman from Montana who testified to the fact that the warming of the planet has begun to warm the streams and waters in which the trout live, and it has made them sluggish, because they are—forgive me for what may be an overstatement, but I think it is not scientifically—they are essentially suffocating as a result of the warming of the water.

Dr. Hall, 2 weeks ago you testified before a House committee that "We need to do something about climate change starting yesterday, and it needs to be a serious effort to try and control greenhouse gases." I want to thank you now for that clear statement about the urgent need to take substantive action to address climate change, and I hope it resonates here in the Senate.

Many of us here on this Committee, obviously, and beyond, want to see the Service expeditiously issue the conclusion that we personally believe science and the Endangered Species Act dictate with regard to the polar bear. Studies commissioned by Interior Secretary Kempthorne from the USGS concluded, as Chairman Boxer said a moment ago, that two-thirds of the world's polar bear population could be lost by the middle of this century. These studies go on to State that that may in fact be a conservative prediction as we are watching Arctic sea ice now disappear at a faster rate than the computer models have projected.

I think we are also, many of us, concerned by the last-minute delay in taking final action on the listing decision. And some, Director Hall, and I hope you will testify to this, are troubled by the coincidence between that delay and the sale of some drilling leases that would affect the polar bear. I think this is an opportunity both for you, Mr. Director, to clarify those matters, and for us to ask you further questions.

I thank you for your presence here, and again, Madam Chairman, I thank you for convening this hearing.

[The prepared statement of Senator Lieberman follows:]

STATEMENT OF HON. JOSEPH LIEBERMAN, U.S. SENATOR FROM THE STATE OF CONNECTICUT

Thank you, Madame Chairman.

Many here will recall that the first hearing Senator Warner and I held in our subcommittee last February was on the impacts of global warming on wildlife. In that hearing, we heard of the ways in which unchecked global warming is harming and, in the absence of action, will increasingly harm species and entire ecosystems that are integral to our way of life and the wellbeing of human societies around the world. We heard in that hearing, nearly a year ago today, that Fish and Wildlife Service Director Hall had identified a warming climate, and the resulting melting of sea ice, as the primary reason that polar bears were threatened as a species.

I am glad that the process that in some sense began with that February hearing culminated last month in our committee reporting the Lieberman-Warner Climate Security Act to the full Senate. I am proud that this committee showed the leadership take the first step toward protecting all wildlife and ecosystems from the damaging effects of catastrophic climate change.

Director Hall, 2 weeks ago, you testified in the House that "We need to do something about climate change starting yesterday, and it needs to be a serious effort to try and control greenhouse gases."

I want to express my deep appreciation to you now for that clear statement about the urgent need to take substantive action to address climate change. I hope it resonates here in the Senate.

We are here today in part because many of us up here want to see the Service expeditiously issue the conclusion that science and the Endangered Species Act clearly dictate with regard to the polar bear. Studies commissioned by Interior Secretary Kempthorne from the USGS concluded that two-thirds of the world's polar bear population could be lost by the middle of this century. They go on to State that this may be a conservative prediction as we are watching Arctic sea ice disappear at a faster rate than models had predicted.

And, in part, we are here because many of us are concerned by the last-minute delay in taking final action on the listing decision, and the troubling coincidence between that delay and the sale of some drilling leases that would affect the polar bear. I look forward to hearing Director Hall's testimony, and to asking him some questions.

Thank you, Madame Chairman.

Senator BOXER. Thank you so much.

Senator Craig.

OPENING STATEMENT OF HON. LARRY CRAIG, U.S. SENATOR FROM THE STATE OF IDAHO

Senator CRAIG. Madam Chair, I will be brief.

I am just beginning to acquaint myself with this issue, and I have not read all of these studies, to be thorough in my examination of it. I am looking at some obvious things. And one of the trend lines that I watch, living in the Pacific Northwest, relates to the Marine Mammals Protection Act that we passed in 1972 and the consequence of that. In my home area, the consequence, of course, of seals, sea lion populations almost exploding up and down the Pacific Coast have resulted in where we now have seals and sea lions contributing substantially to the depletion of salmon runs, or the damage of young fish and all of that, because it is a natural prey base.

It is also true that during that time we did something else. We reduced the human take of the polar bear, and numbers within polar bear populations have moved up substantially from 1965, a guesstimated 8,000 to 10,000, to today 20,000 to 25,000 polar bears. So the polar bear itself, at least in the current environment, is, population-wise, if these figures are accurate, doing quite well in part because of an action this Congress took some time ago.

I also understand the climate change movement, the emotion involved and all that. I know that it is very difficult to predict the future and therefore to extrapolate out of it therefore what will become of these populations. I also have watched over the years as different organizations have used the Endangered Species as a wedge or a sledgehammer to change and modify human action and/or activity within certain areas. That is a given. If you are going to do something within an area that is relatively pristine, you will probably get, somebody will find a species to file to stop you. That is a new tool in the tool kit of human interest that is a part of the public policy we have here.

So I am here to listen and, Director, I am glad you are with us to see where we are in all of this. I hope, as a government, we don't rush to judgment. At the same time, I think we are moving expeditiously now and appropriately in the climate change area. And history will only say, was it us or was it mother nature? Because that question still is on the books.

Thank you.

Senator BOXER. Senator, thank you very much.

I wanted to point out that you were right about the numbers, because we used to allow hunting of polar bears. And therefore the——

Senator CRAIG. Yes, the take was down substantially.

Senator BOXER. Dramatically down. And then when we said only subsistence, that brought them up. What we are talking about today is not hunting, we are talking about the natural environment.

Senator CRAIG. Well, we also did something else, Madam Chair, with the Marine Mammals Act. We increased, we populated their prey base substantially more with seals and sea lions. Those things that the polar bear hunts, we increased those numbers. So obviously their food base was up, their take was down. Mother nature did the math. Thank you.

Senator BOXER. Well, thank you. I think we are in agreement as to the history, which is very important. Because today we are looking at this other threat, not the hunting threat, but the habitat threat.

So I think everybody has spoken, so we will now go to you, Mr. Hall. Welcome, and we look forward to your remarks.

STATEMENT OF H. DALE HALL, DIRECTOR, U.S. FISH AND WILDLIFE SERVICE, DEPARTMENT OF THE INTERIOR

Mr. HALL. Thank you, Chairwoman Boxer, and Ranking Member Inhofe, and good friend, and other members of the Committee who are also friends.

It is really a pleasure to be here with you today and I ask that my full written statement be entered into the record.

Senator BOXER. Without objection, so ordered.

Mr. HALL. As you are aware, the Service proposed to list the polar bear as a threatened species throughout its range on January 9th, 2007. This proposal was based upon scientific review which indicated that the polar bear populations may be threatened by receding sea ice. Sea ice is used by polar bears for platforms for activities essential to their life functions, but especially hunting for ice seals, their main prey.

At the time Secretary Kempthorne announced the proposal, he had directed us to work with USGS, the public, pertinent sectors of the scientific community to broaden understanding of what factors affect the species and to gather additional information to form the final listing decision basis. To assist in that effort, we opened a 3-month public comment period and held public hearings in Anchorage and Barrow, Alaska, and in Washington, DC. We then hosted a meeting in June 2007 of all the range states around the circumpolar, with official representatives from all the countries. The meeting provided a forum for the exchange of scientific, management and technical information among all the range nations.

Then in September 2007, USGS scientists supplied nine new research reports to the Service, updating population information on polar bears in the southern Beaufort Sea of Alaska, and provided new information on the status of two other polar bear populations as well. USGS studies provided additional data on Arctic climate and sea ice trends and projected effects to polar bear numbers throughout the species range. As a result of the new USGS research findings, we reopened the comment period and later extended a second comment period to allow the public time to review and respond to this USGS science.

We expect to provide a final recommendation to the Secretary and to finalize a decision on the proposal to list the polar bear as a threatened species within the very near future.

I would like to discuss current, ongoing efforts to conserve the polar bear as well. While much attention has been focused on the proposed listing of the polar as threatened under the ESA, it is important to realize that the polar bear is currently protected under a number of statutes, treaties and agreements, including the Marine Mammal Protection Act, CITES, or the Convention on International Trade in Endangered Species of Wild Fauna and Flora, under the Endangered Species Act, the 1973 agreement between all five range states, and the Inupiat-Inuvialuit Agreement. These protections, which address take, trade and management, remain in place regardless of the final listing decision.

In addition, the Service has been and is continuing to work a wide range of partners, including the State of Alaska, Alaska Natives, the oil and gas industry and other Federal agencies, scientific organizations, foreign countries, all within the range of the polar bear, and the sporting and conservation communities on a number of efforts to conserve polar bears. The Service and its partners are working on coordinated efforts to conserve the bear under existing authorities, even if we do not move forward with listing. But if we do move forward with the listing, it would be in addition to these existing authorities.

This broad, landscape level effort focuses on polar bear management coordination, polar bear conservation planning, range-wide implementation of the U.S.-Russia bilateral agreement, and research and monitoring. The polar bear is a messenger of the changing conditions in the Arctic. If we listen and work together, we can help enhance the survival of the polar bear for the long term.

I will also mention today, quickly, that I am sending out today an employee's scientific code of conduct. This sets out standards that includes me and the Fish and Wildlife Service to follow sound scientific codes of conduct as we approach scientific information. That will be the basis, the science in front of us and our code of ethics to follow that science will be the basis for the decision.

I thank you for allowing me to be here today and I would be glad to answer any questions that you might have.

[The prepared statement of Mr. Hall follows:]

TESTIMONY OF H. DALE HALL, DIRECTOR, U.S. FISH AND WILDLIFE SERVICE, DEPARTMENT OF THE INTERIOR, BEFORE THE SENATE ENVIRONMENT AND PUBLIC WORKS COMMITTEE ON EXAMINING THREATS AND PROTECTIONS FOR POLAR BEARS

January 30, 2008

Chairman Boxer, Ranking Member Inhofe, and Members of the Committee, I am H. Dale Hall, Director of the U.S. Fish and Wildlife Service (Service), and I appreciate the opportunity to testify before you today regarding both the proposal to list the polar bear as a threatened species under the Endangered Species Act (ESA) and the current protections provided for polar bears under Federal laws such as the Marine Mammal Protection Act (MMPA).

Under the ESA, a species may be determined to be either an endangered species, defined as one which is in danger of extinction throughout all or a significant portion of its range, or a threatened species, defined as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range, based on one or more of the following five factors:

- Present or threatened destruction, modification or curtailment of its habitat or range;
- Overutilization for commercial, recreational, scientific or educational purposes;
- Disease or predation;
- Inadequacy of existing regulatory mechanisms; or
- Other natural or manmade factors affecting its continued existence.

This determination is to be based solely on the best scientific and commercial data available and after taking into account any efforts being made by any state or foreign nation, or any political subdivision of either, to protect such species. The determination may be based on any of these factors or a combination of the factors. The ESA does not distinguish between natural or manmade causes.

As Committee Members are aware, on January 9, 2007, the Service proposed to list the polar bear under the ESA as a threatened species throughout its range after a scientific review of the polar bear found that populations may be threatened by decreasing sea ice extent and coverage and inadequate regulatory mechanisms to address sea ice recession. Polar bears use sea ice as a platform for many activities essential to their life cycle, especially hunting for their main prey, ice seals. The polar bear listing proposal was based on both observed and projected future effect of the expected modification or curtailment of polar bear habitat or range, specifically from receding sea ice, and the absence of any known regulatory mechanisms at the national or international level effectively addressing this threat to polar bear habitat. As part of the scientific review for the listing proposal, the Service also considered the possibility of effects from oil and gas development, hunting, and subsistence harvest and determined, based on a review of various factors, that these activities do not threaten the polar bear rangewide.

At the time Secretary of the Interior Dirk Kempthorne announced the proposal, he directed the U.S. Geological Survey (USGS) to perform new research aimed at providing additional analysis designed to assist our process of moving from a proposed rule to a final rule. The Secretary also directed the Service to work with the public and pertinent sectors of the scientific community to broaden our understanding of what factors affect the species and to gather additional information to inform the final decision on whether the species warrants Federal protection under the ESA. The Service opened a three-month public comment period and held public hearings in Anchorage and Barrow, Alaska and Washington D.C. In June 2007, the Service hosted a meeting of countries that are part of the polar bear's range that included official representatives from the United States, Canada, Norway and Russia. Greenland, which is part of Denmark, was also represented. The meeting provided a forum for the exchange of scientific, management and technical information among the range nations.

In September 2007, USGS scientists provided the results of their new research to the Service. This research included an evaluation of polar bears occupying similar physiographic ecoregions and a determination of how the observed and projected changes in sea ice translate into changes in polar bear habitat availability and status. It updated population information on polar bears of the Southern Beaufort Sea of Alaska, and provided new information on the status of two other polar bear populations (Northern Beaufort Sea and Southern Hudson Bay). USGS studies also provided additional data on arctic climate and sea ice trends and modeled probabilities of change to polar bear numbers throughout the species' range over various time periods.

As a result of the new USGS research findings, the Service reopened and later extended a second comment period, which closed on October 22, 2007, to allow the public time to review and respond to the USGS findings. At the time the decision was made to reopen and extend the comment period, I alerted the Department that the Service might need extra time to adequately evaluate and incorporate results from the comments received. The Service received numerous comments on the USGS reports and has been working to incorporate the USGS findings, as well as to analyze and respond to the information provided during this extended comment period.

The Service expects to provide a final recommendation to the Secretary of the Interior and to finalize a decision on the proposal to list the polar bear as a threatened species under the ESA in the near future.

POLAR BEAR CONSERVATION

The Service working with key partners including the State of Alaska, Alaska Natives, the oil and gas industry, other Federal agencies, science organizations, foreign countries within the range of the polar bear and the sporting and conservation communities, has a number of programs or efforts in place which provide conservation benefits to the polar bear.

The polar bear is currently protected under the Marine Mammal Protection Act (MMPA). The MMPA, enacted in 1972, places an emphasis on habitat and ecosystem protection and sets forth a national policy to prevent marine mammal species or population stocks from diminishing to a point where they are no longer a significant functioning element of the ecosystem. The Secretaries of Commerce and the Interior have primary responsibility for implementing the MMPA. The Department of the Interior, through the U.S. Fish and Wildlife Service, manages polar bears, walruses, manatees and sea otters. The Department of Commerce has responsibility for whales, porpoises, seals and sea lions. The incidental take provisions of the MMPA ensure that any population-level effects on the polar bear will be negligible and will not have an unmitigable negative effect on the availability of the species for subsistence use by Alaska Natives.

The Service and its partners have also started working on coordinated efforts to conserve polar bears under our existing authorities. These efforts will focus on polar bear management and coordination; polar bear conservation planning, range-wide; implementation of the U.S.-Russia Bilateral Agreement[1]; and research and monitoring, and represent an ongoing approach to utilizing and depending upon the expertise, authorities, and support of our State, Federal, Alaska Native, and non-governmental partners. International collaboration will also be fundamental to the success of efforts to address polar bear conservation in the near and long term, using a broad, landscape-level, inter-disciplinary approach.

In addition to the MMPA and the proposed status under the ESA, the polar bear is protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the 1973 Agreement between all five range states, and the Inupiat-Inuvialuit Agreement. This latter agreement is a voluntary agreement between two Native groups – one Alaskan and one Canadian – that harvest polar bears for cultural and subsistence purposes. The Agreement covers the Southern Beaufort Sea population, and harvest under the agreement is monitored by the Service's marking and tagging program. Illegal take or trade in Alaska is monitored by the Service's law enforcement program. All of these protections remain in place regardless of the final listing decision under the ESA.

[1] Agreement between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population.

CONCLUSION

In conclusion, I look forward to working with you as we move forward on this important issue. The Service recognizes that the polar bear faces significant challenges across its range, but we will continue to work with all stakeholders, including the State of Alaska, Alaska Natives, industry, the sporting and conservation communities and foreign governments to conserve the polar bear throughout its range. Rest assured, we are actively utilizing our resources to make an informed decision, based on the best available scientific and commercial data available. I appreciate the opportunity to be here today and am happy to answer any questions you may have.

Senator BOXER. Thank you very much, Director Hall.

Did your staff present a recommendation to you on the listing of the polar bear?

Mr. HALL. We have received the first draft and now the second draft that we are working on that includes the staff's recommendations.

Senator BOXER. So you have received the staff recommendations?

Mr. HALL. Yes, ma'am.

Senator BOXER. OK, then why haven't you acted?

Mr. HALL. Because I am working with staff to get the document in the proper mode, so that it clearly explains all of the questions that we received. We had 670,000 comments, both pro and con, people that argued for and against.

Senator BOXER. Right.

Mr. HALL. And it is not just making the decision. It is being able to have the Congress and the public understand the decision——

Senator BOXER. Right, but you do understand that there is a timeliness associated with this because of the lease sale, right?

Mr. HALL. Yes, ma'am, I do. And I want to say that this delay is my responsibility.

Senator BOXER. Well, let me just say, I wouldn't want to have that responsibility on my shoulders, to think that these polar bears could lose a huge among of their population because you are delaying. I just want to say this. Look at Mr. Johnson. Mr. Johnson of EPA denied a California waiver. He hasn't given us one ounce of paperwork to support it. He is working on it now.

The fact is, it is not unprecedented. So it seems like when it is a delay, that allows special interests to move forward, there is a delay. But when it is the reverse, we don't get the paperwork.

According to Bruce Woods, an agency spokesman in Anchorage, Alaska, the completed work on the decision by the polar bear scientists in the Alaska field office was sent to headquarters December 14th. What was the conclusion of the listing recommendation that was transmitted from the Alaska field office on December 14th?

Mr. HALL. Madam Chair, it would be inappropriate for me to share recommendations internal until the Secretary has made a final decision. Then all of that is part of the public record that would be available. But in the internal workings, the recommendations is to me, then I put together my recommendation for the Secretary and then we move forward from that.

Senator BOXER. But you do understand the timeliness?

Mr. HALL. Yes, ma'am, I do.

Senator BOXER. You do understand that there is a lease sale? You do understand that that is going to move forward, and you do understand that you are late under the law in this decision?

Mr. HALL. Yes, ma'am, I do.

Senator BOXER. The Endangered Species Act allows for a delay in noticing a listing beyond the 1-year deadline only in situations of substantial scientific uncertainty. Am I correct that you have not filed a notice with the Federal Register that this is the reason for your delay?

Mr. HALL. That is correct.

Senator BOXER. What is the reason for your delay?

Mr. HALL. The reason for the delay really started back when we received the USGS reports and we went out for public review. I alerted the Department at that time that it was quite possible that our staff would not be able to work through all of that volume of information and put the packages together to get all the information——

Senator BOXER. So your delay is because there was a lot of public comment?

Mr. HALL. The delay is because of not just the public comment. It is the quality of the answer that is important, too. We received public comments and we owe those public comments the opportunity to really be evaluated and then reported back on.

Senator BOXER. Was there an overwhelming feeling in those public comments whether to list or not list?

Mr. HALL. The public comments are really to ask about the science. And there was good support, I don't have a percentage breakdown, but the vast majority of the support of the comments came in, supported the science that would support a listing.

Senator BOXER. I understand. So there weren't that many diverse views expressed in the public comments? They essentially fell under the category of list it because the science is on your side to do so?

Mr. HALL. We did not believe that, referring to your first question, we did not believe that there was ample scientific disagreement to warrant using that clause of the Act.

Senator BOXER. But you do understand that what you are doing is outside what the law requires you to do. And you do understand that there are many people who suspect some kind of situation going on here between MMS. Have you been in communication with anyone at the White House about the listing rule, anyone at all?

Mr. HALL. No, ma'am.

Senator BOXER. Has anyone contacted you about the timing of your decision from the White House or the Vice President's office?

Mr. HALL. No, ma'am. I notified the Secretary, the Secretary notified the White House that we were going to be late. And that was the extent of the comments.

Senator BOXER. Director Hall, is it true that as of today, it has been 630 days since Fish and Wildlife Service has listed a single species in the U.S. under the Endangered Species Act?

Mr. HALL. I don't have that number in front of me, so I don't know.

Senator BOXER. That is our understanding. And if that is correct, it is the longest delay in the history of the Act. You are delaying the listing of the polar bear, saying there is more work to do. You have legal obligations to protect imperiled natural heritage. So again, I don't quite get it. I appreciate your taking blame for the delay. But your answer is disturbing. Because while you say you care about the science, it looks like there is a lot of science.

I just put in the record USGS report, peer-reviewed. And as a result of your delay, this isn't just, oh, you know, I will wait for a sunny day to make my decision. There is going to be a drilling in an area where 20 percent of these magnificent creatures reside.

So again, I would hope that you would reconsider this. Because everything we do has consequences. And this consequence is something that is going to be pretty disastrous for all of us.

Mr. HALL. Please understand, Madam Chair, I do not take this lightly. But I am committed to having a quality decision out that answers all of the questions. Because this is a very high profile decision. And we will move as fast as we possibly can. But I don't want to over-push our staff. And that is an honest answer.

Senator BOXER. Can you do this before February 6th?

Mr. HALL. That is the projected date that—we had a press conference and said it would probably take us in the neighborhood of an additional 30 days, and we are still pushing to make that.

Senator BOXER. Can you do it by February 6th?

Mr. HALL. The only answer I can give is that we are pushing to try and get there.

Senator BOXER. Well, I would urge you, because even if you have to work overtime, and I will be happy to, if you needed some staff assistants who would work, this Committee would help you, if you needed just some more hands to do this.

It would mean a lot to me as Chairman and I know to many of my colleagues as well.

Mr. HALL. Our staff has worked very, very hard.

Senator BOXER. I understand, and we are willing to give you more resources if you need those.

Senator Inhofe.

Senator INHOFE. Thank you, Madam Chairman.

Let me first of all exchange Scriptures with my good friend, Senator Lieberman. It is Romans 1:25, "Who exchanged the truth of God for a lie and worshiped the creation rather than the Creator."

Senator LIEBERMAN. Well, I was about to say amen, brother, but I think this may lead to a longer theological discussion.

[Laughter.]

Senator INHOFE. I will accept the amen.

Senator LIEBERMAN. I think we honor the Creator by honoring and protecting His creation. But I am glad to be engaged at this level of dialog. It is a good one. Good source.

Senator INHOFE. All right. Administrator Hall, there seems to be a lot of concern about the halting of gas production and all that. You heard my opening statement.

In your proposal to list the polar bear, the Fish and Wildlife Service found no impact on polar bears, due to oil and gas activities. Now, I can remember so well back in the old Alaska Pipeline days when they said the effect this was going to have on the caribou. It has been my experience, particularly in the summer months when I go up there, that the caribou are using the pipeline as the only shade around. So would you elaborate on why these activities would not affect the polar bear, oil and gas production?

Mr. HALL. In our proposed rule of January 9th, 2007, we go through the five-factor analysis. There are five factors in the Endangered Species Act that start with habitat and go down to other man-made or natural causes. One of those activities that we reviewed was oil and gas operation on the North Slope. We looked back over 30 years of operation up there. And especially since the implementation of the Marine Mammal Protection Act regulations, and about 1993, we have been able to document no mortality of the polar bears as a result of oil and gas operations.

So our conclusion in that draft was that oil and gas operations was not in and of itself a significant factor threatening the species.

Senator INHOFE. That is good. I read that, and it is much more. So I would like to ask you to elaborate on that for the record and get into some more of the details. That is very good, I appreciate it.

Now, there is a great deal of concern about the ramifications of the listing on activities elsewhere in the Country. For example, could the emissions of a new power plant in my State of Oklahoma, Oklahoma City, contribute to sea ice decline in the Arctic and therefore harming the bears' habitat. The environmental groups have made it clear that they want to force these associations so that they can regulate greenhouse gases elsewhere.

In last week's House hearing, you disputed that. Could you kind of walk us through that one?

Mr. HALL. Thank you, Senator, because this is one of those areas that I believe that there is some misunderstanding about what the law can and cannot do. When I say the law I mean the Endangered Species Act.

When we talk about consultation between two Federal agencies under Section 7, the first question that is asked is, and the agency does this, is may this, the proposed action, may it affected a listed species. And if the answer is yes, and that determination is usually made by the action agency. Then the next question that they have to ask is, is it likely to adversely affect the species. And if the answer to that question is yes, then that leads you into formal consultation, as most people understand it.

The problem that we face, and Madam Chair was correct a while ago in saying that if you have the scientific evidence then you would have to consult. The issue here, though, for the Endangered Species Act, is both in law and in science. In order for, and I will go with the law first, both the Supreme Court of the United States in the Sweet Home case, and the Ninth Circuit flowing that and the Arizona Cattle Growers Association case, directed that yes, we may implement take for the destruction of habitat. Take means to harm a species, and we have to authorize that.

But in doing so, we must make, as Justice O'Connor called it, the proximal cause case. We must be able to say that this action leads to this take. And but for that action, take would not have occurred. That is a burden that is on us in regulating under the Endangered Species Act. And the Ninth Circuit told us that we could not speculate, that we clearly had to have that chain of evidence that led from this particular action to this particular take.

Now, with that said about the law side, the science today as we know it would not allow us, it doesn't allow us to segregate out specific point source emissions of greenhouse gases and track those to a specific take of a polar bear. And that is the problem that we face in the presumption that is out there, that we would be able to regulate all of this and tie it to the polar bear.

Senator INHOFE. Yes. And I appreciate that, I am sorry to rush you. I do have one more question. It appears to me, and I hate to interject logic into this, but it would seem to me that if we were not to be able to have this, if the connection were made between a power plant in Oklahoma City, therefore something would happen that would be, to halt it in some way, then we would be more dependent upon China and places where they don't have the controls that we have.

Last, and if it is all right, Madam Chairman, since we will take the time off from our scriptural exchange——

Senator LIEBERMAN. But I thought it was timeless.

Senator INHOFE. Very good.

This is a quote: "There is no evidence to suggest that ice in the Arctic Basin disappeared entirely during either of these two warming periods." Now, the two warming periods we are talking about were the Glacial Maximum, about 8,000 to 9,000 years ago in the mid-Holocene warm period, 10,000 to 11,000 years ago. In any of these warming periods, which were of equal or greater warming than predicted by the IPCC's climate warming modelers, nor did any ice-dependent species become extinct. Will this factor into your decision?

Mr. HALL. We are factoring in all historic data that we are able to calculate, including the speed of the warming, along with the end result of the warming temperature. Because we are analyzing for a species, for a living animal and how it might or might not be able to adjust to that. And there are differences in the length of time that it took for the warming to occur in those earlier periods than the length of time that it appears to be taking today.

Senator INHOFE. Thank you.

Senator BOXER. Thank you.

Senator Lautenberg?

Senator LAUTENBERG. Madam Chairman, it feels like we are on the precipice here, it feels like we are on the edge of the precipice, the race between getting the protection for the polar bear in place and the rush to start the process for drilling. I would like to see if we can't make certain that the drilling permits are contingent upon the outcome, Mr. Hall, of the report that you have on polar bears.

I heard some exchange between you and the Chairman, have you said that February 6th is not possible?

Mr. HALL. I have not said that.

Senator LAUTENBERG. I heard the language, but I didn't understand the outcome.

Mr. HALL. No, sir. I have said that on January 7th, when I came out and had the news release and alerted people that it would take us approximately another 30 days, my answer is that that is still my goal. That is still the effort that I want to meet.

Senator LAUTENBERG. Well, why couldn't you issue a report that says whatever delays you might have in front of you, that no drilling, that your recommendation, there is no process that begins the drilling exercise should take place?

Mr. HALL. I am not aware that what has come up with MMS is a drilling. It is a lease sale exercise. So——

Senator LAUTENBERG. It is not an insignificant exercise.

Mr. HALL. No, sir, I am not trying to say that it isn't. But under that exercise, our staff in Alaska did work with the Minerals Management Service using the guidelines of the Marine Mammal Protection——

Senator LAUTENBERG. I heard you say that.

Mr. HALL [continuing].—to make sure, which, the Marine Mammal Protection Act is actually a little more stringent in the take prohibition than the ESA is. But they did work with them on that.

Senator LAUTENBERG. Right. But I want to get down to the nub of things and ask, you are a person of some significant respect in the community, the environmental community. Why we can't get an assurance from you that delays that you generously took responsibility for says to me that the Department is not equipped, I mean, you are not the person who is doing the work, you have a team there.

So for whatever reason, you are not guaranteed a finish by February 6th. And I would urge you to use the influence that you have as the Director of Fish and Wildlife to say, you recommend that nothing be done in that area, that you are close to having a report delivered and you would like the opportunity from the other agencies to hold up on anything until we complete. Is this an important study that we are looking at?

Mr. HALL. The important study being?

Senator LAUTENBERG. On the polar bear, on the important species.

Mr. HALL. Yes.

Senator LAUTENBERG. OK.

Mr. HALL. It is an important study.

Senator LAUTENBERG. So if you could give us the assurance that some of us are looking for, that you understand that what you are doing will make a difference in the way we approach the leases. We need your help.

Mr. HALL. I understand your concern.

Senator LAUTENBERG. You have taken responsibility boldly for the delay, so we need your help now to protect the situation as we would like it done.

Now, you said before that you introduced a new code of conduct for the scientists on your staff?

Mr. HALL. Yes, sir. It is not new, it is a followup to the Office of Management and Budget encouragement that we establish scientific codes of conduct.

Senator LAUTENBERG. And what did we do before this? Was the conduct arbitrary, left to the individual?

Mr. HALL. What this one does is it clearly identifies who is in the scientific arena and who isn't.

Senator LAUTENBERG. Was that a question?

Mr. HALL. There were questions in the past about involvement and discussions, and the Secretary wanted to make clear that, I am one of those oddities. My job requires that I have scientific credentials and fish and wildlife experience, so that I am a scientist. At the same time, I am the first leg of the policy development within the Department. So I wanted to make sure, this is something personally important to me, that we make sure that everyone understands that whatever you see coming from the Fish and Wildlife Service is of the highest scientific regard and as much as possibly be done without emotion.

Senator LAUTENBERG. That was not clear before, apparently, otherwise it wouldn't need a review and a restatement?

Mr. HALL. There is also question about our scientific findings.

Senator LAUTENBERG. Last question, please, Madam Chairman. Could an oil spill in that area, what would the effect perhaps of an oil spill in the region that we are talking about the polar bear, do you have any view of what kind of a condition might result to the bear population?

Mr. HALL. In my discussion with our polar bear experts, it is expected that if a polar bear were to get oiled, that mortality would occur because of the natural grooming, the conditioning that the bear goes through, it would ingest the oil. And our polar bear experts assumed that any single bear that would be oiled would likely end up in mortality.

Senator LAUTENBERG. Thank you. Thank you, Madam Chairman.

Senator BOXER. Thank you.

Senator BARRASSO.

Senator BARRASSO. Thank you, Madam Chairman.

Director Hall, thank you very much for being here today. I will get to the polar bear in a second. I wanted to first, there was a letter that the Wyoming delegation sent to Secretary Kempthorne in December. One has to do with the sage grouse. We felt that the right decision was made when it chose not to list the sage grouse. Subsequently, the people of Wyoming, who have always been interested in protecting the sage grouse and its habitat, have formed working groups, developed and implemented community-based plans to work with the sage grouse, and with habitat. The game and fish department has limited the hunting season, doing the kinds of things we want to do to help with recovery.

There has been a lawsuit, the Western Watersheds Project, and a court ruling. And we understand that requests for documents have been made. The Wyoming delegation has, in this letter, asked that we could please get copies of all the documentation used to support these decisions. We have not received those yet, it has been about 6 weeks. I am just asking that if you could make a note of that and get a look, and we can get a copy of this letter to you again requesting some of those helpful documents.

Mr. HALL. OK.

Senator BARRASSO. But we appreciate the decision that was made regarding this and agree with it. We just want to make sure that we get to see what else is going on there, because we are doing everything we can as a State to help protect this.

Mr. HALL. And the States are doing a very good job of working with us on this, and we do appreciate it.

Senator BARRASSO. Thank you very much.

With regard to the polar bear, and Senator Inhofe had a question about a hypothetical case of what the impacts would be if there is a project in Oklahoma, we have similar questions in Wyoming; how far does this go with potential greenhouse gas emissions and what impact they may have in contributing to these issues. If we are building a road and that is going to allow more cars to be driven with emissions, how far does this go and what can the impact be with all activity which may contributing to the issues of global climate change?

Mr. HALL. How far it goes, in my narrow view of the world, in implementing the Endangered Species Act, I have to stay within those legal decisions that I cited a minute ago. We have to stay within the strength and the maturity of the science.

As I was explaining earlier, I don't believe that it is possible for us to meet the legal standard of having the proximal cause, cause and effect to reach take for emissions done somewhere else on the globe and be able to use the science that cannot make that connection for us. Right now, the greenhouse gas concentrations discussions are really discussions from all sources. They do talk about general breakdowns.

But to be able to track something from the action, which is what we must analyze for an agency, to a point of effective, we have to have the science that makes that clear bridge and tracks that there. My response is, we can't get there today with the level and maturity of the science that we have.

So when you reach out into CAFE standards or into industry or other things, other aspects, including our own homes, we don't know yet how to break that down and make that connection and have that be responsible for the loss of polar bears, or any other species that we might have listed. That is the requirement under the law for us to be able to do that.

Senator BARRASSO. Thank you, Director Hall. Thank you very much, Madam Chairman.

Senator BOXER. Thank you, Senator Barrasso.

Senator LIEBERMAN.

Senator LIEBERMAN. Thanks, Madam Chairman.

Thanks, Mr. Hall. It strikes me, I don't know whether we should put this in the record, but you are a career Fish and Wildlife Service person. You come to the directorship from that. So you have spent your life in this work, and I appreciate that. To me, that gives you some credibility as you testify before us.

I mentioned in my opening remarks the study commissioned by Senator Kempthorne from the U.S. Geological Survey that concluded that two-thirds of the world's polar bear population could be lost by the middle of this century. I just want to ask you, not at great length, but generally, whether you viewed the USGS survey as a credible survey?

Mr. HALL. We do view the USGS science as credible science. And the prediction that they made in that science was not necessarily that two-thirds of the polar bears would be gone, but that two-thirds of the habitat that they need to survive would be gone.

Senator LIEBERMAN. Right.

Mr. HALL. That was the prediction they made there. And then they stepped that over into other studies and talked about the bear population.

Senator LIEBERMAN. Got it, OK. I appreciate that. So it has some credibility. We had a series of questions about the timing of the oil and gas leases and the Chukchi Sea, as related to the decision about whether to list the polar bear in the ESA. I just wanted, for the record, to ask you if you would describe the additional, to the best of your ability in this testimony, the additional steps the Federal Government would need to take in examining the proposed Chukchi Sea lease sale, if the polar bear were first to be listed as a threatened species under the ESA. I understand, as you alluded to earlier, that there are other laws, notwithstanding the ESA, that require some steps to be taken with regard to wildlife.

But what additionally would be required if the ESA listing occurs?

Mr. HALL. The only thing additional that would be required would be a formal Section 7 consultation that would be added to the Marine Mammal Protection Act consultation and the OCS Act requirements. If the lease sales went forward, then the next steps would be industry proposals. And they start to get very specific. Then we would consult under each of those laws again for each of those steps along the way.

So the only additional thing would be a Section 7 consultation on top of the Marine Mammal Protection Act and on top of the other things that are there.

Senator LIEBERMAN. Right. Just briefly, what does the Section 7 consultation involve?

Mr. HALL. The Section 7 consultation is under, obviously, Section 7 of the Act that requires that no Federal agency undertake an activity that might jeopardize the continued existence of a species.

Senator LIEBERMAN. OK, that is important. Finally, the work done by the Minerals Management Service in considering the Chukchi Sea leases included some environmental impact statements. In the EIS that the MMS obtained, there was a recognition that there was a 40 percent chance of a large crude oil spill, 26 percent for a pipeline spill and 19 percent for a platform spill as a result of the Chukchi Sea activities. The Minerals Management Service acknowledges that, predicts, I suppose, that between 750 and 1,000 oil spills are likely from its proposal to open up the Chukchi Sea to oil and gas development.

The reason I mention this is that while, in my opinion, clearly the most significant threat to the existence of polar bears today is the loss of the sea ice habitat and as has been said, access to prey, it does seem to me that the oil and gas development that were being, or leases that were being talked about and relevant development, is also a source of some danger of a different sort to the polar bears. Would you agree?

Mr. HALL. Yes, sir.

Senator LIEBERMAN. Thank you. Thank you for your testimony. Thanks, Madam Chair.

Senator BOXER. Thank you, Senator.

Senator CRAIG.

Senator CRAIG. Dale, again, thank you very much for your testimony. This is one Senator that is not going to ask you to rush the science. Get it right, as best you possibly can. I am amazed that there is even an implication or a suggestion by any Senator that the science ought to be rushed. Because we have questioned the science of your agency over time. Was it political science or was it good biological science?

I am also always a little disturbed when U.S. Geological gets into the biological business instead of the geological business as to their credibility. Your credibility is important here, and the work you do is important. I recognize you and the Secretary for establishing a protocol for your science and reinforcing it. Credibility in that process is very, very important.

So get the science right. I don't want to use it as a block, I don't want you to rush it to stop a lease sale, because you have just mentioned to Senator Lieberman the process. And there is a process. Because it is clearer that there are some Senators who want to use this as a blocking tactic. That is pretty clear by the line of questioning that has gone on here today.

Once the lease sale is released and leases are bought, there is a process, the application for a Federal permit to drill. That is where Section 7 comes into play, it is my understanding. And everything must be done within that process by the company to meet the standards that you set down in that process, to mitigate as best they can against any degradation to the environment and/or to the species that might be involved, is that not correct?

Mr. HALL. It is, sir, and it happens at each step, from the seismic activity to the expiration to the development.

Senator CRAIG. In other words, all human activity that might result from a lease sale in the Chukchi Sea would require that kind of process, would it not?

Mr. HALL. Yes, sir, at each step of the way.

Senator CRAIG. Would your agency, during that process, have people in place to observe and to participate in those activities, if a lease sale went through, if a permit to drill were allowed, and if those standards were developed, how would you monitor those?

Mr. HALL. Historically, and we have worked with the National Marine Fisheries Service for observers to be present in areas where we had overlapping jurisdiction, in this case marine mammals. The National Marine Fisheries Service has most of the marine mammals and we have four or five of them. So the National Marine Fisheries Service does generally have observers out on ships for fishing and we would expect that there may be that case here for oil and gas development.

Senator CRAIG. You would expect that that might be the case, or you would believe that that would be the case?

Mr. HALL. I don't know the answer to that yet. We would have to wait until, as we move forward into the process.

Senator CRAIG. Thank you very much.

Senator BOXER. Senator Klobuchar.

Senator KLOBUCHAR. Thank you, Chair.

It is good to see you again, Director Hall. I thank you for traveling to Minnesota on a very cold day to attend our national Pheasants Forever convention. We were excited to have 10,000 people there. I spoke, I think you spoke.

Mr. HALL. Yes, ma'am.

Senator KLOBUCHAR. It was very good.

I was actually also surprised at the number of hunters and wildlife people there that mentioned climate change to me. As you know, I talked about cellulosic ethanol in my speech, and our concern about the effect that the changing world is having on our lands and their sport. So I just wanted to mention that for the record as well.

But today we are talking about the polar bear. I will say I am concerned, having not been here for too long, but realizing that the first petition to list polar bears was made in February 2005. And here we are, 3 years later, now still being told that a decision is in the future. With the Intergovernmental Panel on Climate Change predicting a total loss of summer sea ice in as soon as 30 years, the USGS study mentioned by Senator Lieberman, which is predicting a loss, as you clarified, of habitat by two-thirds, I just don't think we can afford to keep delaying.

My questions are about, first of all, the listing. Some people claim that a threatened listing for polar bears would create some kind of patchwork of regulation, when taken together with the Marine Mammal Protection Act and international agreements on polar bear conservation. What are your views on this? Are there ways to simplify this? I am just trying to figure out why this would create a problem.

Mr. HALL. I think the way I would like to answer that, because I am not exactly sure of the patchwork, but let me just say that the standards for marine mammals, under both the Endangered Species Act and the Marine Mammal Protection Act for the protective standards are very close. And as a matter of fact, in some cases, the Marine Mammal Protection Act that is in place is more protective.

So obviously, if a species were listed, that is a marine mammal, if it were listed under the Endangered Species Act, one of the first things we would want to do is synchronize the Marine Mammal Protection Act and the Endangered Species Act operations and reviews so that——

Senator KLOBUCHAR. Would there be additional protections that would come into effect if you were to list it?

Mr. HALL. I am not sure. And the reason that I say that is under the Marine Mammal Protection Act, the standard, for example, the oil and gas operations that were just being talked about, the standard under the Marine Mammal Protection Act is no negligible harm. And under the Endangered Species Act, an agency would be able to move forward and avoid jeopardizing the species. Those standards are obviously very far apart.

So in that regard, the Marine Mammal Protection Act is far more protective.

Senator KLOBUCHAR. Could you describe the impact that this polar bear listing, if it happens, will have on Federal and State climate change initiatives? The argument has been made that if a listing compels the Government to protect habitat and the habitat loss has been caused by global warming, then a listing might compel Government to take action. Do you think that is true?

Mr. HALL. I think that the polar bear, as I said in my oral comments as I opened, is that the polar bear is a message for us here. But I think it would be a mistake to hang too much on, even if we list or don't list, it's too much to hang it on any given species. If climate change is an issue that we want to address, and I believe that all Americans want to make sure that we don't do something that we can't reverse, that will leave harm for our future generations, then I think we need to address it as a societal world issue as well.

Symbols like the polar bear help to galvanize and help to get people to understand the significance. But the Endangered Species Act simply is not the vehicle, I do not believe, to reach out and demand all the things that need to happen after a good, common discussion about what should happen.

Senator KLOBUCHAR. Our State doesn't have a lot of polar bears, but we have trout and other freshwater fish that, I think there are some good arguments to be made, are going to be threatened by climate change. Is there work being done to look at other animals and fish that may be affected by this?

Mr. HALL. Yes, ma'am. Senator, it is a very good question, I am glad you brought it up. Because it does tend to get lost in the discussion. I think most Federal agencies, almost all State agencies, game and fish agencies that I am aware of, and a lot of foreign nations that we work with are all trying to address the issue of climate change and not tie it to a species, but tie it to a complete type of ecosystem.

For example, I firmly believe that we should be looking at the Arctic as an ecosystem and what will happen? There will be winners and there will be losers as ecosystems change. How do we deal with that? And coming down into the sub-Arctic, but it sure felt like I was in the Arctic when I was in Minnesota, but when you come down into those areas, all of us are working to try and understand much larger questions than a species. I think if we are going to make real progress, that is the way we have to look at it, what can we really learn that will help us understand how species and whole ecosystems will respond to these changes. I really believe that is where the effort should be.

Senator KLOBUCHAR. Thank you.

Senator BOXER. I noted that we have been joined by Senator Warner, who is Ranking Member of the subcommittee that deals with wildlife. I wonder if you would like to make an opening statement and ask Mr. Hall some questions before we move to our next panel.

Senator WARNER. Thank you. I would just like to be listed as one supporting listing as an endangered species, and let's get on with it. I will just put a short statement into the record. I am very envious of the job you have, which is about the only job I would take in trading this one.

[The prepared statement of Senator Warner was not submitted at time of print.]

Senator BOXER. This could be very exciting.

Mr. HALL. Our staffs are still trying to figure out how to get us fishing together, Senator.

Senator WARNER. That is correct, we had that fishing trip planned. Thank you very much.

Senator CRAIG. Come to Idaho, will you two come to Idaho and fish? I'll take you fishing, how is that.

Senator BOXER. Senators, thank you very much.

What I want to do, just in concluding this, is to put a few things in the record and also give to my colleagues a picture that I won't put up here, because it is a very sad picture of a starving polar bear. There are many of us who believe if we don't take action, this is what we will be looking at instead of these magnificent pictures that we have shared today.

So this is what I want to do, I want to put into the record and I want to clear the record on something as well, your mission statement, sir. The mission of the U.S. Fish and Wildlife Service is working with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people. So I think focusing on the ethics, the science and your mission, I think is very, very important.

[The referenced material follows:]

Senator BOXER. I also, because one of our Senators told you, do not rush, I have to take issue with that. There is a law, and the law says you must act. This isn't about one Senator saying, I think this is really important, this isn't about one Senator saying, don't rush or rush. This is about the law. The law says that you needed to act by January 9th of this year. You took full responsibility for the delay, which I appreciate, I really do. You didn't blame anyone else. But the fact is, you didn't file the appropriate papers you were supposed to under the Act.

So you are not obeying the law. That is serious. SO it is not a question of rush or don't rush. You need to obey the law. And as Chairman of this Committee, I urge you to obey the law.

Now, you are delinquent, but the quicker you act now, and again, if you need to work overtime, a lot of us will help you with, go through these comments, whatever it is you need, we will make available to help you.

But I think it is really key, and I want to put into the record the citing of this section of the law that requires you to act. It is the Endangered Species Act, 16 U.S.C. 1533(b)(6). So again, if you or I broke the law outside of this, just a law outside of the Senate, there would be consequences. We wouldn't just sit there and say to the judge, I am sorry, I am not obeying the law. There would be consequences.

Now, the consequences for taxpayers is, you are going to be sued. There has already been an intent filed, because you didn't follow the law. So I think this is key.

And then just to lighten it up a little, I thought I would put into the record another very interesting quote, made in the year 500 A.D. in a commentary on Genesis. One of the great rabbis said, "See my handiwork, how beautiful and choice. Be careful not to ruin and destroy my world, for if you ruin it, there is no one to repair it afterward."

So I think this is something that we all feel strongly about. Now, we may come at it in different ways. But I think we all feel strongly about it. I think this has been a very important hearing. Mr. Hall, I just want you to know, I am completely at your disposal to help you move forward on this.

Was there anything else?

Senator CRAIG. Madam Chair, in a sense of fair play, may I take just a moment?

Senator BOXER. Yes.

Senator CRAIG. Certainly when I suggested to the Director that he get the science right, I was not suggesting and I must ask that the record show that he violate the law to do so. You implied that I might be suggesting that by your statement. I did not do that.

I believe that when we do good science, then we can create good policy. And if this is a question of getting it right, get it right. But it was not my intent, Madam Chair, to suggest that he violate the law to do so. Thank you.

Senator BOXER. Well, I am really glad, because you did say, "don't rush." And the point is——

Senator CRAIG. And then I said, "Get the science right."

Senator BOXER. Yes, well, we all want that.

Senator CRAIG. Thank you. Let's keep it in context.

Senator BOXER. No, no, no. I am very happy you clarified it. I just wanted to make the point that there is a date certain. Mr. Hall took responsibility for the delay. I am encouraging him to use whatever resources at his disposal to save this creature. And I think it is very important, because while we are delaying here, we are rushing on a lease sale here. There is, in many people's minds, a connection to the two.

Thank you very much. We are going to move forward. Yes, of course.

Senator WARNER. I won't take but a minute. Any of us who were fortunate to raise a family of young children, as I did, know that at some point in their life, the house is scattered with panda bear toys. In a way this is the panda bear for the Atlantic region, count it on down. There is a great fascination about this magnificent beast.

I would just ask, are there other things we could do, apart from putting it back on the species list, or keeping it on, whatever the case may be, are there other Federal policies that could be invoked to help?

Mr. HALL. Well, sir, as I alluded to a minute ago——

Senator WARNER. Well, if you have already covered it——

Mr. HALL. No, no, I only alluded to it with the other question. And that is that this is a much larger issue. The bills that you have in Congress looking at ways to approach greenhouse gas management and making sure that we are doing what we can to control, those are larger issues than the Endangered Species Act. That was really the point that I wanted to try and make, is that to rely on the Endangered Species Act to make those kinds of decisions, in my opinion, takes it out of the realm of this discussion, where it really needs to be.

Senator WARNER. Last, are there any other species of animals that are similarly in peril in the Arctic region?

Mr. HALL. We will be looking at the Arctic. There are questions about the movements there as well. But climate change has regional impacts. It may be sea level rise on the Gulf Coast and in your part of the world. It may be droughts in the Southwest. It may be floods in other areas and rain instead of snow in the mountains for that summer water that is so important out west.

We need to address this, I believe, on a regional basis, working together.

Senator WARNER. I thank the witness and thank the Chair.

Senator BOXER. Thank you. Yes, we thank you, sir. We will be in close touch.

We will call up panel two, Margaret Williams, Director, Bering Sea Ecoregion and Russia projects, from the World Wildlife Fund; Andrew Wetzler, Director, Endangered Species Project, from the NRDC; Brendan Kelly, Ph.D., Associate Vice President for Research, University of Alaska; Richard Glenn, Alaskan Arctic resident and sea ice geologist; J. Armstrong, Ph.D., Professor of Marketing, The Wharton School, University of Pennsylvania.

We welcome all of you. I know you have been very, very patient. We really are happy, and we are going to start right in, if you can take your seats quickly.

Ladies and gentlemen, I am going to ask you to do what we didn't too well here, which is to keep your opening remarks to the 5-minutes. My Ranking Member, I really want him to be here to question, and he has a tight schedule.

So we will start with you, Dr. Kelly. We are very happy you are here representing the World Wildlife Fund.

STATEMENT OF BRENDAN P. KELLY, PH.D., ASSOCIATE PROFESSOR OF MARINE BIOLOGY, ASSOCIATE VICE PRESIDENT FOR RESEARCH, UNIVERSITY OF ALASKA

Mr. KELLY. Thank you. Senator Boxer, Senator Inhofe, members of the Committee, I appreciate the opportunity to share with you my assessment of the threats posed to polar bears by climate change.

The Fish and Wildlife Service brings bad news that none of us wants to hear. I must confess that when I was asked to review their proposed listing and the supporting documents, I was looking forward to finding some critical flaw in their analysis or the conclusions. That is not what I found, however. Instead, I found that they have carefully assembled the best available information and conducted a thorough and thoughtful analysis.

For over 30 years, I have studied the marine mammals that inhabit Arctic seas. During those three decades, I have witnessed dramatic changes in the sea ice environment that provides essential habitat to seven species of seals, to walruses and to polar bears. Most dramatic has been the decease in the seasonal duration and extent of sea ice. I have seen in the graphic—can we put that graphic back up that shows the ice retreat? As seen in this graphic, the summer ice extent has been reduced almost by one half. The Intergovernmental Panel on Climate Change, the American Geophysical Union and the vast majority of sea ice physicists predict that there will be no summer sea ice in the Arctic within this century, possibly within 30 years.

The loss of over 8 million square kilometers of summer sea ice will endanger many plants and animals that are adopted to that once extensive habitat. Polar bears will be especially negatively impacted, as they are adapted to a narrow niche; namely, hunting seals on sea ice.

Polar bears began to separate from the brown bear population several hundred thousand years ago. Eventually, and I stress eventually, that new line of bears began to specialize on hunting seals and walruses that were abundant on the Arctic sea ice.

A key feature of that specialization was the evolution of teeth specialized for meat-eating, quite different from the brow bear's teeth, which reflect a more generalist diet. Thus polar bears, like the seals they prey upon, and many Arctic organisms, are specifically adapted to the sea ice environment. In the absence of summer sea ice, such specialized species will be threatened by competition from other species, by the disappearance of prey, by the loss of breeding habitat and by potential hybridization or inter-breeding with other species.

Without summer sea ice, polar bears will overlap for longer periods with brown bears in habitat to which brown bears are better adapted, putting the polar bears at a competitive disadvantage.

Food will be less available to polar bears, as populations of their ice-associated prey decline. Their main prey, the ring seal, depends on spring snow cover to successfully raise their pups. And increasingly early snow melts associated with climate change are exposing those seal pups to predation at extreme temperatures.

Emergence of female and young polar bears from dens in the spring coincides with the seals' birthing season and the newly emerged bears depend on catching and consuming young seals to recover from months of fasting. The match in timing between polar bear emergence and the availability of young seals may be disrupted by changes in the timing and duration of snow and ice cover.

The polar bear's ability to capture seals depends critically on the presence of ice. Hunting on the ice, bears take advantage of the fact that the seals must surface to breathe in limited openings in the ice. They have evolved complex behaviors for locating and capturing the seals on the ice.

On the open ocean, however, bears lack a hunting platform. Seals are not restricted in where they can surface, and successful predation is exceedingly rare. Only in ice-covered waters are bears regularly successful at hunting seals. When restricted to shorelines, bears feed little, if at all.

The most obvious change to the breeding habitat is the reduction in snow cover on which successful denning depends. Female polar bears hibernate for four to 5 months each year in dens in which they give birth to cubs, each weighing about one pound. Those small cubs depend on the snow cover to insulate them from the cold.

Some criticisms of the proposal to list polar bears as threatened reflects misconceptions about the predictions of climate models and the predictions of population models. There are fewer and fewer serious critics of climate models, and that is not surprising when you consider the marked consistency of the 23 major models and their abilities to reconstruct past climates.

While models developed in different laboratories vary from one another in terms of the exact amount of warming predicted in the coming century, they all predict warming. None predict cooling or even a stable climate. The reliabilities of the models is also seen in their tremendous power to accurately reconstruct global temperatures for the past 750,000 years, as recorded in ice cores. Models that can accurately hindcast for a million years are a good bet for forecasting. Thus, it is the that pronounced future climate warming and melting of ice is the overwhelming consensus view in the scientific community.

While climate models can be validated in using temperature records and ice cores, population models do not have a comparable record for validation.

Senator BOXER. Sir, you are going to have to finish, because you are going way over time.

Mr. KELLY. OK. I will just finish by saying that the approaches used by the Fish and Wildlife Service and the USGS have been well tried and evidence their efficacy in other species. I don't think we need to wait for a body count to know that these reductions are happening. The most recent IPCC reports that the resilience of many ecosystems is likely to be exceeded by the year 2100.

[The prepared statement of Mr. Kelly follows:]

Testimony submitted to
Senate Committee on Environment and Public Works

Hearing on
Examining Threats and Protections for the Polar Bear

Wednesday, 30 January 2008

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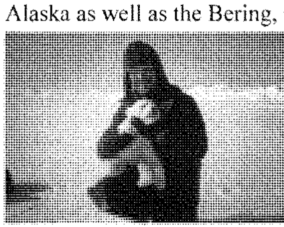
Observed reductions of Arctic sea ice

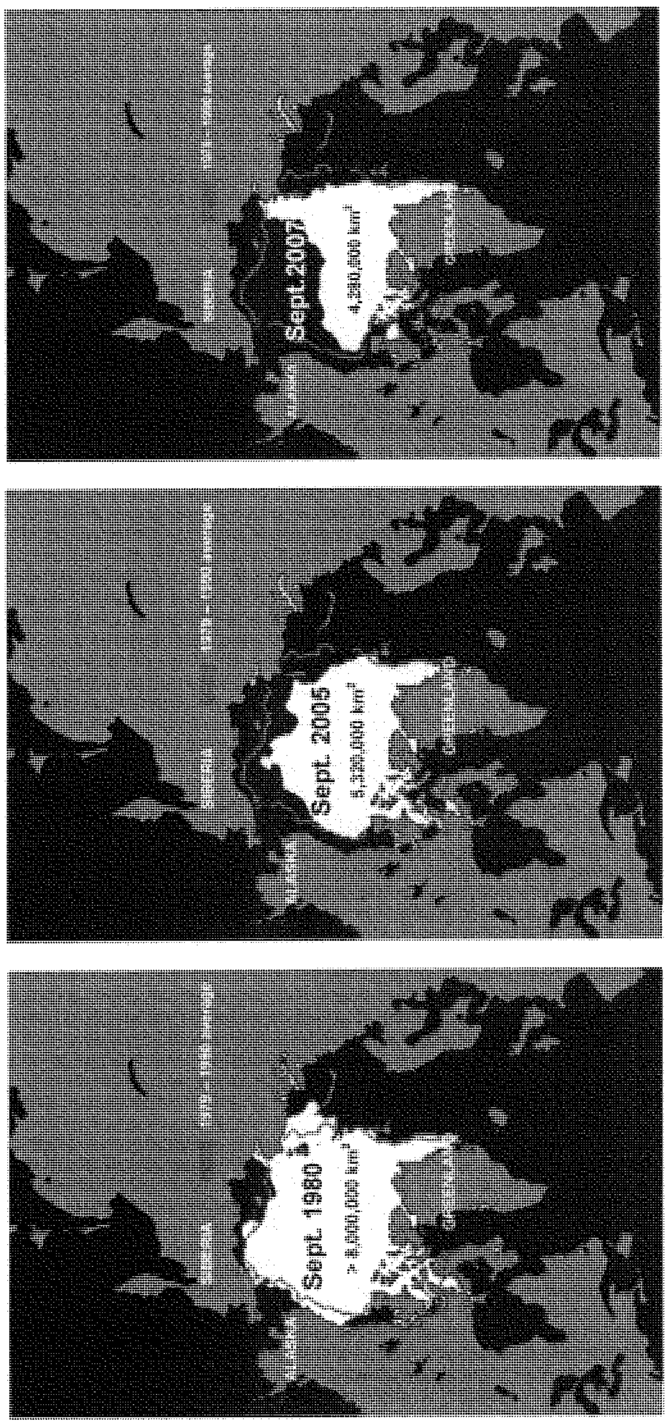


For over thirty years, I have studied the marine mammals that populate the Gulf of Alaska as well as the Bering, Chukchi, and Beaufort seas. During those three decades, I have witnessed dramatic changes in the sea ice that provides essential habitat to 7 species of seals, walruses, and polar bears. Eleven of the 12 warmest years since 1850 were recorded between 1994 and 2006, and one result has been that the seasonal duration and extent of the ice decreased substantially. As seen in the figure on the next page, the summer sea ice extent has been reduced by almost one half. The Intergovernmental Panel on Climate Change, the American Geophysical Union, and the vast majority of sea ice physicists predict that there will be no summer sea ice in the Arctic Ocean before the current century is over, perhaps within the next 30 years.

Polar bears are specialists, adapted to hunting on sea ice

The loss of over 8,000,000 km^2 of summer sea ice will endanger many species of plants and animals adapted to that once extensive habitat. Polar bears especially will be negatively impacted as they are adapted to a narrow niche, namely hunting seals from the sea ice.

The narrow niche occupied by polar bears can be contrasted to that of brown bears who occupy a greater range of habitats and whose diet is much broader. Genetic data indicate that polar bears began to separate from a brown bear population (probably in southern Alaska) 150,000 to 250,000 years ago. Molecular biology does not tell us when that new line of bears began to specialize in hunting Arctic seals, but the oldest fossils showing the



National Snow and Ice Data Center

specialized meat-eating teeth that distinguish today's polar bears from brown bears are as recent as 20,000 years old.

Specialization to preying on ice-inhabiting seals was not without its costs, and the polar bear's feeding success is strongly related to ice conditions; when stable ice is over productive shelf waters, polar bears can feed throughout the year on their primary prey, ringed seals. When the ice is absent, however, the bears lack a platform from which to capture surfacing seals.

Today, an estimated 20,000 to 25,000 polar bears live in 19 apparently discrete populations distributed around the circumpolar Arctic. Their overall distribution largely matches that of ringed seals, which inhabit all seasonally ice-covered seas in the Northern Hemisphere, an area extending in winter to approximately 15,000,000 km^2. The broad distribution of their seal prey is reflected in the home ranges of polar bears which - averaging over 125,000 km^2 - are 200 times larger than the averages for brown bears. Most polar bear populations expand and contract their range seasonally with the distribution of sea ice, and they spend most of year on the ice. Most populations, however, retain their ancestral tie to the terrestrial environment for denning, although denning on the sea ice is common among the bears of the Beaufort and Chukchi seas. Dens on land and on ice are excavated in snow drifts, the stability and predictability of which are essential to cub survival.

Loss of sea ice too rapid for successful adaptation

The rapid rates of warming in the Arctic observed in recent decades and projected for at least the next century are dramatically reducing the snow and ice covers that provide denning and foraging habitat for polar bears. These changes to their environment will exert new, strong selection pressures on polar bears. Adaptive traits reflect selection by past environments, and the time needed to adapt to new environments depends on genetic diversity in populations, the intensity of selection, and the pace of change. Genetic diversity among polar bears is evident in the 19 putative populations, suggesting some scope for adaptation within the species as a whole even if some populations will be at greater risk than others. On the other hand, the nature of the environmental change affecting critical features of polar bears' breeding and foraging habitats, and the rapid pace of change relative to the bears' long generation time (about 15 years) do not favor successful adaptation.

Threats from changes in breeding habitat

The most obvious change to breeding habitats is the reduction in the snow cover on which successful denning depends. Female polar bears hibernate for four to five months per year in snow dens in which they give birth to cubs, typically twins, each weighing just over 1 lb. The small cubs depend on snow cover to insulate them from the cold.

Threats from changes in foraging habitat...........

Changes in the foraging habitat that will entail new selection pressures include seasonal mismatches between the energetic demands of reproduction and prey availability; changes in prey abundance; changes in access to prey; and changes in community structure.

...... mismatches in timing

Emergence of female and young polar bears from dens in the spring coincides with the ringed seal's birthing season, and the newly emerged bears depend on catching and consuming young seals to recover from months of fasting. The match in timing between bear emergence and the availability of young seals may be disrupted by changes in timing and duration of snow and ice cover. Such mismatches between reproductive cycles and food availability are increasingly recognized as a means by which a variety of animal populations are impacted by climate change.

...... reduced prey abundance

Recognized as the most abundant of northern seals, ringed seal populations also are likely to decline as the sea ice habitat changes. Like polar bears, ringed seals depend on snow caves for rearing their young, and increasingly early snow melts have led to high rates of seal mortality due to hypothermia and predation. Walruses and bearded seals also are preyed upon by polar bears, and feeding and reproduction of those animals likewise is tightly coupled to the sea ice environment.

...... reduced access to prey

The polar bear's ability to capture seals depends on the presence of ice. In that habitat, bears take advantage of the fact that seals must surface to breathe in limited openings in the ice cover. In the open ocean, however, bears lack a hunting platform, seals are not restricted in where they can surface, and successful predation is exceedingly rare. Only in ice-covered waters are bears regularly successful at hunting seals. When restricted to shorelines, bears feed little if at all, and terrestrial foods generally are of little significance to polar bears.

...... changes in biological community

Seal and other prey populations also will be impacted by fundamental changes in the fate of primary production. For example, in the Bering and Chukchi seas, the reduction in sea ice cover alters the physical oceanography in ways that diminish nutrient flow to bottom-dwelling organisms and increases nutrient recycling closer to the ocean surface. The resultant shift in the composition of the biological community will impact all branches of the food web, including polar bears. The exact composition of future biological communities in the Arctic Ocean is not known, nor is it known how effectively polar bears might exploit those communities.

Projected population reductions and possible extinctions

The rapid rate at which snow and ice cover is declining, will work against successful adaptation by polar bears. Populations are likely to be reduced and extinction could result from mortality outpacing production and/or from hybridization with brown bears.

The U.S. Fish and Wildlife has made a careful analysis of the threats and prudently recommended listing polar bears as threatened. They accurately summarized the preponderance of evidence that the loss of sea ice will threaten polar bears. They have used the best available information to project likely changes in population levels. We cannot expect those projections to be precise in terms of actual numbers, but we have every reason to believe that population changes will be large and downward given the magnitude of sea ice loss.

The impacts of small changes in habitat can be difficult to predict, but the impacts of whole-sale loss of critical habitat are more obvious. If a lake shrinks, its fish population likely will be stressed but survival of the population is quite possible. If the lake dries up completely – even if only seasonally - the fish population will not survive. Sea ice is essential habitat to polar bears just as lake water is to fish, and the U. S. Fish and Wildlife Service's proposal to list polar bears as threatened is appropriate and timely.

Senator BOXER. We're going to have to stop you there. Because we just told everyone to stick with 5 minutes.

So next is Margaret Williams, of the World Wildlife Fund. Welcome.

STATEMENT OF MARGARET WILLIAMS, MANAGING DIRECTOR, KAMCHATKA/BERING SEA ECOREGION PROGRAM, WORLD WILDLIFE FUND

Ms. WILLIAMS. Thank you, Madam Chair, and members of the Committee. It is an honor to speak to you on the subject of protecting polar bears and their habitat.

My name is Margaret Williams, and I represent the World Wildlife Fund, WWF, an international conservation organization with 1 million members in the U.S. and 5 million members worldwide. For more than 20 years, World Wildlife Fund has been an active player in the Arctic, and polar bears and other Arctic species have been a major focus of our work.

I have submitted my full written testimony for the record, but in the next few minutes, I would like to speak about the history of polar bear protection and recommend actions to protect the species. Many of those who oppose the listing of the polar bear under the ESA, the Endangered Species Act, State that polar bears today are more numerous than they were 40 years ago. That is correct. This is because polar bears were over-harvested by trophy hunters into the middle of the 20th century, when numbers dipped to the low thousands.

Fortunately, the U.S. took action with the passage of the Marine Mammal Protection Act in 1972. A year later, the U.S. took further action for polar bears, signing on to the International Agreement for the Conservation of Polar Bears, committing our Nation to "take appropriate actions to protect the ecosystems in which polar bears live."

The U.S. is also party to another international treaty, which is aimed specifically at conserving a polar bear population which we share with Russia, the Alaska-Chukotka, also known as the Chukchi population. While the MMPA and these international agreements provide an important framework for conservation, today more is needed to protect polar bears. The leading threat to the species is climate change, and we have heard a lot of the data this morning. In the last three decades, the Arctic has undergone a major transformation. Arctic summer sea ice has shrunk by approximately 10 percent per decade since 1979, the equivalent of the area the size of California and Texas combined.

For a species whose life cycle entirely depends on the ice, this means less time to hunt and eat, leading to declines in body condition, reproduction and ultimately declines in survival. These facts have been well documented in hundreds of peer-reviewed scientific papers, including a report by the Nobel prize-wining Intergovernmental Panel on Climate Change.

A compelling body of work explaining the relationship of polar bears to sea ice was complemented last fall by a series of comprehensive reports by the U.S. Geological Survey. And again, we have heard it, the USGS shows that two-thirds of the world's polar bears, including America's two populations, could be lost by mid-century. Based on this unequivocal science and based on the requirements of the Endangered Species Act, the polar bear must be listed as threatened.

While climate change is the primary threat, other factors must also be considered. As the health of the species is compromised, we must eliminate other sources of stress and disturbance. One such factor is oil and gas development, concern over which was expressed by the Polar Bear Specialist Group in 2001, and this is the world's preeminent body on polar bears, when it reported that industrial development of oil and gas resources and consequent increases in shipping are major concerns as future threats for polar bears and their habitats.

The issue is now very pertinent, because in 2 weeks, the Minerals Management Service, MMS, will conduct a lease sale for oil and gas in 29 million acres in the Chukchi sea, the home range of a species whose future is already tenuous. MMS has acknowledged a huge lack of information about the wildlife in this marine area, home not just to polar bears, but seals, whales, walrus, and remarkable numbers of birds. In fact, MMS ignored the advice of the National Marine Fisheries Service, which recommended removing the Chukchi Sea entirely from the MMS 5-year program.

In regard to the delay——

Senator BOXER. Say that one more time.

Ms. WILLIAMS. The National Marine Fisheries Service recommended removing the Chukchi Sea from the MMS 5-year plan on oil and gas development, the plan from 2007 to 2012, which just went into effect in July.

In regard to the delay in its decision on listing the polar bear, the U.S. Fish and Wildlife Service explained that additional time was needed to conduct necessary data analyses. Yet MMS is not following the same example, instead, rushing forward for no clear reason on the Chukchi sale. Just as the U.S. took action 30 years ago to help the polar bear, we must do the same today. In addition to listing the species under the ESA on a global scale, this means drastically reducing CO_2 emissions and other greenhouse gases and on a regional scale, delaying the lease sale on the Chukchi Sea until there is adequate information and until adequate measures have been put in place to protect polar bears and their habitat.

In closing, I would like to say that on nearly a daily basis I am in contact with scientists and conservation colleagues from around the Arctic. They are eagerly waiting to see how and whether the U.S. will protect polar bears and their Arctic habitat. Indeed, the world is watching us. I urge the Secretary of Interior to do the right thing for the polar bear and for the planet. I applaud this Committee's attention to this important species.

Thank you.

[The prepared statement of Ms. Williams follows:]

Testimony of Margaret Williams
Managing Director
Kamchatka/Bering Sea Ecoregion Program
World Wildlife Fund

before the

Committee on the Environment and Public Works
U.S. Senate

"Examining Threats and Protections for the Polar Bear"

January 30, 2008

Chairwoman Boxer, Ranking Member Inhofe, and Members of the Committee: on behalf of the World Wildlife Fund (WWF), I am pleased to provide you with comments on this very important topic -- the future of polar bears and polar bear habitat, particularly of our polar bear populations here in the United States.

WWF is an international conservation organization with 1.2 million members in the US and over 5 million members worldwide. WWF has been involved in Arctic conservation for over 20 years, and we have offices and field programs in all of the circumpolar Arctic countries.

My own educational and professional background is in conservation biology and policy and for ten years I have been director of WWF's Bering Sea Ecoregion Program, which involves work on both the Alaskan and Russian coasts of this region. In the last several years I have been working closely with Alaska and Russian polar bear biologists and community members to address changes in bear distributions and increasing human-bear interaction, particularly in the Russian Arctic. I am a member of the Council on Foreign Relations and also formerly the chair of WWF's international Arctic team.

Polar bears, the charismatic icon of the polar environment, have long been a focus in WWF's on-the-ground research and conservation projects in the Arctic. Polar bears are an essential part of the Arctic ecosystem: as an apex predator, polar bears also serve as bellweathers for the state of their northern surroundings, an indicator of health for the Arctic.

Polar bears also comprise a central part of Arctic indigenous cultures. For example, Chukchi native people in the Russian Arctic for years practiced ancient rituals and celebrations honoring the polar bear, and today the species remains part of the subsistence cultures of people of Alaska, Greenland and Canada.

Polar bears – and the issue that brings us together today at this hearing -- are also important for their ability to captivate the public's attention. During the public input period for the USFWS' proposed listing of polar bears, hundreds of thousands of comments were generated – a staggering number – indicating the intense interest in the fate of this species.

I. Threats to Polar Bears

Today polar bears face a very serious threat. Analyses recently published by the US Geological Survey show that by mid 21st century, two-thirds of the world's polar bear population could be lost, mainly due to loss of sea ice. As this sea ice habitat decreases, the entire food chain will be affected – from the tiniest plankton to the forage fish, the ringed seal, and the king of the north, the polar bear.

The impacts of global warming on polar bears have been well-documented and are described in World Wildlife Fund's public comments regarding the proposed listing, included as an appendix to this document. In summary, climate change will impact polar bear habitat, polar bear prey, and the reproduction and survival of polar bears. Some of those impacts are as follows:

A. Climate Impacts on Polar Bear Habitat

The most fundamental characteristic of polar bears in relation to their ecology is their utter dependence on sea ice habitats (Derocher et al. 2004). Anything that significantly changes the distribution and abundance, let alone the very existence of sea ice will have profound effects on the persistence of polar bears on Earth. Such habitat loss or fragmentation is well documented to be a primary cause of extinctions (Beissinger 2000, Ceballos and Ehrlich 2002).

Experts agree that the once-characteristic ecotype of the far north is undergoing an unprecedented and accelerating warming trend (ACIA 2004, Serreze et al 2000, Parkinson and Cavalieri 2002, Comiso 2002a, 2002b, 2003), shifting from arctic to subarctic conditions, and in some cases profoundly altering the fundamental biological components that are usually associated with the Arctic realm (e.g. Grebmeier et al. 2006). This consensus confirms what has been known for some time by Native peoples inhabiting this region (e.g. ACIA 2004, WWF *Climate Witness Program* testimony www.panda.org/arctic).

B. Climate Impacts on Polar Bear Prey

Sea ice also is the preferred habitat for polar bears' main prey: ringed and bearded seals (Smith 1980). Polar bears are specialists on these phocid seals, only rarely and opportunistically taking other prey, like walrus, small whales, or other seals (Derocher et al. 2002). Of concern is how accessible prey species will be in an altered sea ice environment. Sea ice is the physical platform from which polar bears hunt; they only rarely capture prey successfully in open water (Furnell and Oolooyuk 1980). The emerging warmer climate regime is likely to negatively impact polar bears both by reducing the duration, thickness, and extent of available hunting habitat (as described above) and also by reducing populations of these two obligate prey species, which, like polar bears, are sensitive to perturbations in the sea ice environment and related changes in primary productivity (Derocher et al. 2004). In illustration of this, changes in ice characteristics have been documented to have a significant negative effect on population size and recruitment of ringed seals and subsequently of polar bears (Stirling 2002). Thus, predicted and observed changes in its distribution, characteristics, and timing of sea ice certainly have the potential to profoundly and negatively affect the species at the population level (Stirling and Derocher 1993, Derocher et al. 2004).

C. Climate Impacts on Polar Bear Reproduction and Survival

Changes to ice habitats also affect polar bear denning opportunities, ultimately reducing population reproductive success. For pregnant bears that den on land, ice must freeze early enough in the fall to allow them to walk or swim to the coast. As the distance from ice edge to coasts increases, it will become progressively more difficult for them to reach their preferred locations (Derocher et al. 2004). For females that den on multiyear ice rather than stable land, increased drift rates of this habitat could mean longer distances to travel with new cubs to reach the core of their normal home range (Derocher et al. 2004).

Such increased energy expenditure by individual polar bears could result in both lower survival and reproductive rates in the long term (Derocher et al. 2004) by reducing stores of fat tissue, thereby impacting body condition.

D. Other Threats to Polar Bears

1. Oil and Gas Development and Transport

Active oil and gas exploration, extraction, and transportation activities are increasing throughout the Arctic. As bear populations are compromised due to climate-related stress, the increase of offshore oil activities represents a particular concern. Polar bears are sensitive to oiling in the event of a spill (Stirling 1990), and their behaviors can be affected by disturbances related to hydrocarbon development (such as seismic blasting and infrastructure development; Derocher et al. 1998). Currently proposed offshore extraction activities pose the greatest threat to polar bears, especially if a spill occurred near a polar bear denning site (Isaksen et al 1998). Also, spills in frozen or partially frozen Arctic waters are hard to detect and no method has proven effective for clean up in this environment.

Finally, should climate warming lead to an open northern shipping route, the threat of a spill would be presented to more northerly polar bear populations, such as Alaska's bears in the Chukchi Sea. Recent accidents and near-misses in Alaska's Aleutian Islands, such as the grounding of the cargo freighter *Selendang Ayu* in 2004, have demonstrated the challenges in responding to such incidents in remote and rough waters of the north.

2. Pollutants and Disease

Many persistent organic pollutants (POPs), as well as heavy metals and radioactive elements, can reach high levels in polar bears due to their high fat diet and high trophic position (Norstrom et al 1998). Studies have demonstrated that such chemicals can negatively impact endocrine function (Skaare et al. 2001), immune function (Bernhoft et al 2000), and subsequent reproductive success (Derocher et al. 2003). Immune-compromised, not to mention hungry, bears may be more susceptible to disease or parasites. The northern expansion if range of disease organisms and the nearly complete lack of such organisms in polar bears' evolutionary past also make them vulnerable to novel pathogens (Derocher et al. 20004). Finally, environmental pollutants can cause pseudo-hermaphroditism in female bears, as has been observed in Svalbard, further reducing population reproductive rates.

3. Increased Aggressive Human-Bear Interactions

It has been predicted that human-bear interactions would increase as a result of climate-induced changes to polar bear habitat (Stirling and Derocher 1993). There is a documented correlation between date of ice break-up in spring and number of "problem" bears reported in some communities (Stirling et al 1999). More bears on land, especially if they are hungry, can lead to more attacks on humans and, correspondingly, more "defense of life and property" killings of bears. Just this year, in a remote village on Russia's Chukotka Peninsula, a young woman was killed by an unusually aggressive bear; this was the third reported bear shooting in Russia this winter.

4. Illegal Harvest of Polar Bears

Harvesting of polar bears has historically been the main threat to the species, but this has been largely mitigated through various management regimes (Prestrud and Stirling 2002). However, in some parts of the bears' range, poaching is still a problem that can have profound effects on population persistence. For example, the unregulated harvest of Chukchi Sea polar bears in Russia appears to be significant and raises concern about the status of this population. Notably, large numbers of polar bear hides have been offered for sale on the internet in Russia. Although it has not been proven that the source of these hides is Chukotka, we do know this population is vulnerable to illegal hunting. Although actual harvest levels are unknown, an estimated 250-300 polar bears were illegally taken on Russia's Chukotka Peninsula in 2002. Experts believe this harvest was at least twice the level experienced in previous years and likely resulted from the large number of bears that were stranded on land by an early ice retreat (Ovsyanikov 2003). A recent population viability analysis indicated that, even at a harvest level of 180 bears/year, there would likely be a 50% reduction in this population (which is shared with the U.S.) size within 18 years (Schliebe 2003).

II. Protecting the Polar Bear

This section examines protective measures in place domestically and internationally to protect the polar bear, points out our shortcomings, and demonstrates how listing the polar bear under the Endangered Species Act could help the polar bear.

A. Existing Protections

Currently, polar bears in the United States are protected under the Marine Mammal Protection Act ("MMPA"), enacted in 1972. The primary focus of this legislation, with respect to polar bears, has been the management and reporting of the limited legal harvest of polar bears by Alaska Natives. The MMPA also sets the conditions for specific activities in polar bear habitats, such as oil and gas exploration, development, and production. The MMPA protects the right of Alaskan natives to conduct subsistence harvest of polar bears. MMPA regulations played an important role in curbing rampant trophy hunting that was decimating polar bears throughout their range in the Arctic.

Elsewhere in the Arctic, other protective measures are in place. In Russia, polar bears have been included in the Red Data Book of Rare and Endangered Species and important polar bear habitat has been protected. Wrangell Island, known as the "polar bear nursery" for its large concentration of maternity dens, was designated in 1976 as a federally protected strict nature reserve, and surrounded with a 30-mile marine buffer zone. Russia continues to protect polar bear habitat, as evident in the establishment of regional sanctuaries, national parks, and community-managed areas in the Arctic. In Norway, hunting is prohibited and large protected areas have been established around polar bear habitat. In Canada, the species is under consideration for addition to the Species At Risk Act (SARA) list.

There are two international legal instruments to which the US is a party that commit the US government to protecting the polar bear and its habitat. The first is the 1973 International Agreement on the Conservation of Polar Bears. This treaty, like the MMPA, grew out of concern in the 1950s and 1960s about the increase in sport hunting of polar bears and the decline in polar bear populations throughout their range. High numbers of bears were being hunted as trophies for their hides. Those opposed to listing the bear under the ESA correctly point out that today polar bears are more numerous than they were 40 years ago. Throughout the 20th century, across the Arctic, from Canada to Russia, bears were being over-hunted. One scientist estimated that more than 150,000 polar bears had been taken in Eurasia between the late 18th Century and the late 1970s (Stirling, I, 2002). However, action was taken to recover polar bears.

Ironically, considering the State of Alaska's position against listing the polar bear (See "Bearing Up, New York Times editorial by Alaska Governor Sarah Palin, Jan. 5, 2008), the move to protect polar bears 40 years ago was in large part due to the efforts of an Alaskan leader. In 1965 Secretary of Interior Stewart Udall credited Alaska's Senator Bartlett with "awakening the public interest in the preservation of the polar bear" (see attached FWS press release). It was thanks to Senator Bartlett that the first international meeting of polar bear experts was convened – and hosted at the University of Alaska, Fairbanks—to address the problem of declining polar bear populations. Out of this first international event held in September, 1965, grew the Polar Bear Specialist Group (PBSG) (Young and Osherenko 1993). Formed in 1968, the PBSG today is considered the preeminent scientific body regarding polar bears.

Following two more meetings of the new Polar Bear Specialist Group and a series of draft protocols on protecting polar bears, four nations agreed to meet in Oslo, and representatives of Canada, the US, Norway, and Denmark sign the International Agreement on the Conservation of Polar Bears. (Later the Soviet Union would sign). In 1981 the five range states agree to extend the agreement indefinitely, and today this agreement is still in force.

Most notable for today's discussion is Article II of the Agreement, which states that "*Each Contracting Party shall take appropriate action to protect the ecosystems of which polar bears are a part, with special attention to habitat components, such as denning and feeding sites and migration patterns, and shall manage polar bear populations in accordance with sound conservation practices based on the best available scientific data.*"

Further reinforcing this point, Article IV states that "*Each Contracting Party shall enact and enforce such legislation and other measures as may be necessary for the purpose of giving effect to this agreement.*" Protecting the polar bear under the Endangered Species Act constitutes one of those necessary measures.

Another international agreement, which was negotiated over many years, is the US-Russia Agreement on the Conservation and Management of the Alaska-Chukotka Polar Bear Population. The agreement was signed by both countries in 2000, then ratified by the US Senate in 2003 and went into effect in 2007. As a preamble to the agreement, both parties affirmed "*that the United States and the Russian Federation have a mutual interest in and responsibility for the conservation of the Alaska-Chukotka polar bear population*" and recognized that "*reliable biological information, including scientific data and traditional knowledge of native people, serves as the basis for development of an effective strategy for the conservation and management of this population.*" Article III describes that area as being affected by the treaty as "*the waters and adjacent coastal areas subject to the national jurisdiction of the Contracting Parties in that area of the Chukchi, East Siberian and Bering Seas....*" The US-Russia polar bear agreement requires both countries to protect and sustainably manage the shared population of polar bears, whose home range includes both Russian and Alaskan portions of the Chukchi Sea.

While these treaties represent important milestones in polar bear conservation, there are some shortcomings. For example, there have been few meetings of the Parties since the signing of the treaty. Until the US hosted a meeting in June of 2007, the last conference of the parties had been in 1981. The treaty lacks a mechanism to adequately monitor the effectiveness of its overarching goal, and there is an insufficient connection between the Polar Bear Specialist Group and the Agreement (Bankes and Clark, 2007). Finally, there is currently no range-wide, internationally agreed-upon species action plan.

While the US works with its international partners to strengthen this treaty, it should take a stronger stand by listing the polar bear and activating the necessary measures under the ESA. Today, polar bears face a new threat – climate change – and action is needed just as it was forty years ago.

B. The Next Step in Protecting Polar Bears: Listing Under the ESA

The Endangered Species Act (ESA) was intended by Congress to provide a means to protect endangered and threatened species as well as the ecosystems on which they depend. Listing the polar bear under the ESA requires the federal government to take actions not available under other regulatory mechanisms for the protection of listed species.

For example, if the polar bear is listed, the US Fish and Wildlife Service will be required to identify and protect critical habitat for the polar bear. The Service will also be obligated to develop a recovery plan, which provides a science-based "road map" that guides managers responsible for the species. A recovery plan should include site-specific actions, estimates of time and cost of the recommended measures, and criteria for "de-listing" the species.

Additionally, if the polar bear is listed as threatened, the federal government will be required to identify and designate "critical habitat" for the polar bear. The Endangered Species Act defines "critical habitat" as "specific areas within the geographical area occupied by the species" which contain "physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection. Critical habitat can also include "specific areas outside the geographical area occupied by the species."

Finally, the listing of the polar bear under the ESA will prohibit any federal action from jeopardizing the continued existence of the species, or adversely modifying its critical habitat.

WWF supports the USFWS recommendation to list the polar bear as threatened under the ESA. This position is based on:

1) The preponderance of scientific, peer-reviewed papers and studies on the impacts of climate change to the Arctic sea ice

2) The numerous reports over several years from the Polar Bear Specialists Group indicating concerns about the status of polar bears, and the series of reports by our own federal agency, the US Geological Survey, that two-thirds of the world's polar bears could be lost if current climate trends continue.

3) The legal mandate of the Endangered Species Act to protect a species "threatened" or "endangered" species when any of the following criteria are met:

(1) The present or threatened destruction, modification, or curtailment of its habitat or range;
(2) Over-utilization for commercial, recreational, scientific, or educational purposes;
(3) Disease or predation;
(4) The inadequacy of existing regulatory mechanisms;
(5) Other natural or manmade factors affecting its continued existence.

The volume and gravity of scientific, peer-reviewed papers and studies on the impacts of climate change to the Arctic have increased significantly in the last several years and provide a compelling body of science to justify the listing of the polar bears as threatened under the Endangered Species Act.

In the last two years alone, several major studies – including the Noble Prize-winning report by the Intergovernmental Panel on Climate Change (IPCC, 2007), have been co-authored and peer-reviewed by hundreds of well-respected scientists that document evidence of global climate change. These experts have reached widespread agreement that (1) climate change is real; (2) human-caused pollution is the main contributing factor; and that (3) the Arctic is one of the regions experiencing climate change most acutely.

One widely accepted scientific study suggests that abrupt reductions in the extent of summer ice are likely to occur over the next few decades, and that near ice-free September conditions may be reached as early as 2040. In December, 2007, Dr. Jay Zwally of NASA predicted that summer sea ice may be gone as early as 2012 (Associated Press 2007).

Besides diminishing sea ice, other impacts in the Arctic that are already being observed include: shrinking glaciers, thawing permafrost, and Arctic "greening" (encroachment of shrubs and trees into tundra ecosystems) validate -- and in many cases -- exceed predictions made regarding temperature trends, reductions to annual sea ice during the summer and winter periods, reductions to multi-year pack ice and reductions to ice thickness.

For several years, polar bear scientists have recognized these changes and have been warning us about the potential impacts to polar bear habitat from climate changed-induced loss of sea ice.

In 2004, Canada's leading polar bear biologists wrote that: "...polar bears are constrained in that the very existence of their habitat is changing and there is limited scope for a northward shift in distribution. Due to the long generation time of polar bears and the current pace of climate warming, we believe it unlikely that polar bears will be able to respond in an evolutionary sense. Given the complexity of the ecosystem dynamics, predictions are uncertain but we conclude that the future persistence of polar bears is tenuous" (Derocher et al., 2004).

In 2005, polar bear biologists from throughout the world recommended that the World Conservation Union (IUCN) reclassify the polar bear from *Least Concern* to *Vulnerable* (one of the categories which describes species that are "threatened with global extinction"), and the following year, IUCN did indeed add the polar bear to this category.

In 2007, scientists of the US Geological Survey produced a series of compelling reports indicating that if global climate trends continue, two-thirds of the world's polar bear populations could be lost. Among those populations that could witness localized extinctions are the Chukchi and Beaufort Sea populations.

The weight of scientific evidence supports the contention that polar bears' habitat is fast disappearing and that predicted individual and population level effects are already occurring. In the two best-studied polar bear populations in the world, the Western Hudson Bay and the Southern Beaufort Sea, we have witnessed population declines that correlate directly with the decline in Arctic Sea ice.

The sad and undeniable truth is that we are rapidly losing the polar bear's most important key to survival – its sea ice habitat. And there is unequivocal evidence for this: federal agencies have documented late summer Arctic sea ice declining by 7.7 percent per decade, and the perennial sea ice area declining up to 9.8 percent per decade since 1978. In some places, the Arctic sea ice has been shown to be thinning by 32 percent or more from the 1960's and 1970's to the

1990's. These figures are presented in peer-reviewed published data to which Alaska scientists had substantial input. So when Alaska government representatives and other opponents to the listing say that the proposed listing is "based on uncertain modeling of possible effects" (Compass, December 18, 2007) it is surprising to biologists and climatologists around the world. The facts are no longer "uncertain" or "possible" – we are seeing the impacts along the Bering Sea coast from Alaska to Russia.

It is clear that the listing of the polar bear as a threatened species is warranted chiefly because of the "threatened destruction, modification, or curtailment" of polar bear habitat or range, i.e. the sea ice. This is the primary Endangered Species Act standard that counsels listing of the polar bear.

Alaska has some of the world's best polar bear scientists, including one of the leading authors of the now-famous US Geological Survey (USGS) study that was released in September 2007. Based on the status of sea ice and polar bears, the USGS report warns that two-thirds of the world's polar bear populations could be lost by 2050. Other peer-reviewed research has shown negative impacts of declining sea ice. In the western Hudson Bay population, which is not "stable" but decreasing, the ice breaks up three weeks earlier than it did 20 years ago. Scientists have recorded nutritionally stressed bears, lower survival in the population, and a 22 percent population decline.

In another dramatic example of the consequences of shrinking sea ice to polar bears, scientists in 2004 found four dead polar bears floating in the ocean 60 miles offshore of northern Alaska, at a time when the polar ice cap had retreated a record 160 miles north of Alaska's coast. This led a marine biology professor at the University of Alaska to state: *"For anyone who has wondered how global warming and reduced sea ice will affect polar bears, the answer is simple – they die."*

C. Potential for Adverse Impacts to Polar Bears and their Habitat

Currently, as the USFWS deliberates over whether to list the polar bear as threatened under the ESA, another federal agency, the Minerals Management Service, is weighing an important decision which could have some significant impacts on polar bear habitat: the conducting of Lease Sale 193, nearly 30 million acres offshore in Alaska's Chukchi Sea, for oil and gas development.

1. The Chukchi Sea: Why It Matters

Until recently, few people in the American public knew where the Chukchi Sea is located, or why it matters. Yet this Arctic body of water, nestled north of the Bering Strait between Russia and Alaska, is one of the world's most productive seas. Fed by nutrient-rich currents from the Bering Sea and the Arctic Ocean, the Chukchi Sea supports a diverse and dynamic web of life. At the base of food chain are prodigious plankton communities that thrive along the ice edge. They, in turn, support ocean bottom shellfish, and crustaceans, and forage fish, which provide important prey for sea ducks, seabirds, walrus, ice seals, whales, and other marine species. These include populations of ringed and bearded seals which provide a high-energy food source for the ultimate predator at the top of this food chain -- the polar bear.

In addition to polar bears, numerous whale species, walrus, seals, birds and fish exist in the Chukchi Sea. For example, bowhead whales, including mothers and calves, migrate through the Chukchi lease sale area. Gray whales summer in the lease sale area, parts of which (e.g. the Hannah Shoal) contain important feeding habitat. Gray whale use of the Chukchi Sea is increasing, likely as a result of changing prey regimes due to climate change.

The Chukchi Sea provides the "main feeding grounds" for walrus, which are a "species of special concern." This is due to "the importance of offshore habitats within the Chukchi, the documented sensitivity of walruses to anthropogenic disturbances, and the significance of walrus hunting to the economy and culture of indigenous communities in Alaska and Chukotka."

The sea is also home to the Stellar and Spectacled Eider, both of which are protected under the Endangered Species Act (ESA). A portion of the Chukchi Sea, Ledyard Bay, is so important to continued survival of the North Slope breeding population of spectacled eider – the majority of which molt in the bay each summer – that it has been designated as critical habitat under the ESA.

2. Leasing in the Chukchi Sea: a Cause for Concern

WWF joins the conservation community in its grave concern over plans by Minerals Management Service (MMS) to conduct Sale 193 in the Chukchi Sea. This concern is based on several factors:

(i) A series of scientific comments provided by numerous federal agency experts who believe that the Chukchi Sea – and another important place for marine life, the North Aleutian Basin (otherwise known as Bristol Bay) -- should not have been included in the 2007-2012 MMS' Five Year Program for oil and gas development of the Outer Continental Shelf.

(ii) Minerals Management Service's own recognition of the high probabilities of oil spills that could result from development of the Chukchi Lease sale area. Specifically, MMS states that there is a 40% chance of a large crude oil spill; 26% for a pipeline spill; and 19% for a platform spill. MMS also estimates that 179 small crude oil spills could occur, totaling 1,214 barrels, or over 50,000 gallons of oil, in this region (Final Environmental Impact Statement for Oil and Gas Lease Sale 193 and Seismic Surveying Activities in the Chukchi Sea).

(iii) The USFWS in its proposed ruling to list the polar bear stated that although there have been few direct mortalities associated with oil and gas activities, "the greatest concern for future oil and gas development is the effect of an oil spill or discharges in the marine environment impacting polar bears or their habitat."

(iv) To date, there is no proven technology to contain oil spills in the Arctic ice environment. And, unfortunately, there have been thousands of spills already on the North Slope – on land. Over 4,000 spills totaling 1.9 million gallons of toxic substances occurred during a nine-year period, according to the Alaska Department of Environmental Conservation (Alaska Department of Environmental Conservation spill database 1996-2004 (no villages, DEWlines). If this record is any indication of what is to be expected in terms of oil spills and environmental contamination, offshore development in the Chukchi Sea would be highly irresponsible. Indeed, the infrastructure and preparedness in place to address even small spills in the icy, Arctic environment of the Chukchi Sea do not even exist.

3. Overview of the Threat of Oil and Gas to Polar Bears in the Chukchi Sea

Given the importance of the Chukchi Sea to polar bears and the growing climate-induced threats to this species, WWF is concerned about the proposed oil and gas leasing in the region. These concerns are bolstered by the following facts:

(i) A series of scientific comments were provided to MMS by numerous federal agency experts who believe that the Chukchi Sea – and another important place for marine life, the North Aleutian Basin (otherwise known as Bristol Bay) -- should not have been included in the MMS Five Year Plan for the OCS.

For example, in two separate formal written submissions to MMS, the National Marine Fisheries Service (NMFS) raised concerns about MMS's lack of scientific data about how drilling in these Arctic waters could affect wildlife and Native cultures. In comments dated April 10, 2006, NMFS recommended that MMS remove the Chukchi Sea entirely from its proposed 5-year plan due to the critical lack of science:

"*The NMFS Alaska Region believes the proposed leasing schedule is unrealistically ambitious and would not allow for necessary environmental research . . . This is particularly true for the North Aleutian Basin (Bristol Bay) and Chukchi Sea proposed sales.* ***The NMFS Alaska Region recommends deletion of these areas and initiation of a comprehensive research program to support future plans subsequent to the 2007-2012 plan*** *. . . For instance, MMS states repeatedly that little is known about the distribution, abundance, behavior, and habitat use of marine mammals in the Chukchi Sea, and the few existing studies are very dated. It is extremely important to gain a better understanding of these issues prior to any exploration, leasing, or development. The need for baseline data on the distribution of marine mammals in the Chukchi Sea is particularly urgent"* (NMFS Comments on Department of the Interior's Minerals Management Service (MMS) Draft Proposed Outer Continental Shelf (OCS) Oil and Gas Leasing Program 2007-2012, dated April 10, 2006).

Again on January 30, 2007, NMFS raised its concerns with MMS about MMS' lack of scientific understanding of the potential impacts on polar bears, whales, walrus, sea lions and other wildlife from drilling in the Chukchi Sea. NMFS also pointed out serious issues with potential impacts on Native cultures and traditional ways of life:

"*We remain very concerned about potential impacts to living marine resources and their habitats, fisheries, and subsistence uses of marine resources as a result of lease sales, exploration, and development in the Chukchi Sea Planning Area. The individual and cumulative effects of development in these relatively pristine environments could be significant . . .* [Yet MMS's] data to describe marine mammals within the sale area and their habitat use are lacking or inadequate . . . Some of these [scientific data] gaps are striking given the ecological, social and cultural importance of the marine mammals in question" (Comments of the National Marine

Fisheries Service on the Minerals Management Service (MMS) Draft Environmental Impact Statement for the Chukchi Sea Planning Area, January 30, 2007).

(ii) MMS's EIS recognized that there is a 40% chance of a large crude oil spill; 26% for a pipeline spill; and 19% for a platform spill (Final Environmental Impact Statement for Oil and Gas Lease Sale 193 and Seismic Surveying Activities in the Chukchi Sea).

MMS admits that 750-1,000 oil spills are likely from its proposal to open-up the Chukchi Sea to oil and gas development (MMS's Environmental Assessment for the Proposed Oil and gas Lease Sale 20, Beaufort Sea Planning Area, p. 97 and MMS's Chukchi Sea Planning Area Oil and Gas Lease Sale 193 and Seismic Surveying Activities Draft Environmental Impact Statement. 2006. http://www.mms.gov/alaska/ref/EIS%20EA/Chukchi_DEIS_193/DEIS_193.htm).

While clearly the overwhelming threat to polar bears today is the loss of sea ice habitat and access to prey, we must consider other sources of stress to the species. Oil and gas development is certainly one of those sources.

a) <u>Oil and Gas as a Threat to Polar Bears</u>

Polar bears are sensitive to oiling in the event of a spill (Stirling 1990), and their behaviors can be affected by disturbances related to hydrocarbon development, such as seismic blasting and infrastructure development (Derocher et al 1998). In 2001, the Polar Bear Specialist Group, in its final proceedings, stated that "Industrial development of oil and gas resources and a consequent increase in shipping are main concerns as future threats for polar bears and their habitats (Isaksen et al 1998).

At its next international meeting in 2005, the IUCN Polar Bear Specialist Group cautioned that "Expansion of winter-time petroleum exploration and development in the Arctic has increased concerns that oil and gas activities could disturb denning polar bears, resulting in premature den abandonment and cub mortality" (IUCN Polar Bear Specialists Group 2005). Sources of disturbance include noise and vibration from exploratory drilling, construction of ice roads and ice pads, aircraft and ground traffic. Although some experiments have been conducted testing noise levels inside artificial dens, the experts concluded that "there is currently a lack of pertinent information that is necessary to determine how industrial noise and vibration effects on polar bears should be mitigated." Currently the petroleum industry is required to avoid a one-mile buffer around known polar bear den sites. However, the PBSG has pointed out that this distance was arbitrarily established and the required buffer can be overridden if the USFWS provides authorization for "incidental taking" (IUCN Polar Bear Specialists Group 2005).

Also, spills in frozen or partially frozen Arctic waters are hard to detect and no method has proven effective for clean up in this environment. Finally, should climate warming lead to an open northern shipping route, the threat of a spill would be presented to more northerly polar bear populations, such as Alaska's bears in the Beaufort and Chukchi Seas alike.

b) <u>Oil and Gas as a Threat to Other Wildlife Species</u>

Oil threatens nearly all arctic wildlife, and as an apex predator, the polar bear can be harmed if other wildlife is oiled. This section summarizes some of the impacts that oil activities can have on other wildlife.

Oil spills can affect wildlife in numerous ways, depending on location, timing, and weather at time of spill, as well as the type of oil spilled. As oil "weathers" it can adhere to wildlife even more. Marine wildlife will not necessarily avoid an oil spill and in fact may be attracted to slicks that can appear like floating food.

Known impacts resulting from oil, usually crude and bunker fuels, include but are not limited to:

- hypothermia in birds by reducing or destroying the insulation and waterproofing properties of their feathers;
- hypothermia in seal pups by reducing or destroying the insulation of their fur;
- marine mammals such as fur seals become easy prey if oil sticks their flippers to their bodies, making it hard for them to escape predators;
- birds sink or drown because oiled feathers weigh more and their feathers cannot trap enough air to keep them buoyant;
- birds lose body weight as their metabolism tries to combat low body temperature;
- marine mammals lose body weight when they can not feed due to contamination of their environment by oil;
- disguise of scent that seal pups and mothers rely on to identify each other, leading to rejection, abandonment and starvation of seal pups;
- damage to the insides of animals and birds bodies, for example by causing ulcers or bleeding in their stomachs if they ingest the oil by accident.

Other types of less direct impacts of spills can be felt by wildlife. For example, oil persisting in the environment or oil that is ingested can cause:

- poisoning of wildlife higher up the food chain if they eat large amounts of other organisms that have taken oil into their tissues;
- interference with breeding by making the animal too ill to breed, interfering with breeding behavior such as a bird sitting on their eggs, or by reducing the number of eggs a bird will lay;
- damage to the airways and lungs of marine mammals;
- damage to and suppression of a marine mammal's immune system, sometimes causing secondary bacterial or fungal infections;
- damage to red blood cells;
- organ damage and failure such as a bird or marine mammal's liver;

- damage to a bird's adrenal tissue which interferes with a bird's ability to maintain blood pressure, and concentration of fluid in its body;
- damage to fish eggs, larvae and young fish;
- interference with a baleen whale's feeding system by tar-like oil, as this type of whale feeds by skimming the surface and filtering out the water.

(From the Australian Maritime Safety Authority: http://www.amsa.gov.au/marine_environment_protection/educational_resources_and_information/teachers/the_effects_of_oil_on_wildlife.asp).

iii) In its proposed ruling to list the polar bear the USFWS stated that although to date there have been few direct mortalities associated with oil and gas activities, "the greatest concern for future oil and gas development is the effect of an oil spill or discharges in the marine environment impacting polar bears or their habitat." (US Fish and Wildlife Service Proposed Rule pp 1079-1080. Federal Register Vol 72, No 5. Jan 9, 2007])

USFWS noted in its ruling that such activity is "increasing as development continues to expand throughout the United States Arctic and internationally, including in polar bear terrestrial and marine habitats.

Echoing the cautions expressed by the National Academy of Science when it issued a report on cumulative impacts of oil development on Alaska's north slope, the USFWS noted that "A major spill in the Beaufort sea would have major impacts on polar bears and ringed seals. (US Fish and Wildlife Service Proposed Rule pp 1079-1080. Federal Register Vol 72, No 5. Jan 9, 2007).

iv) To date, there is no proven technology to contain oil spills in the Arctic ice environment.

Of great concern in the Chukchi Sea is the lack of known technology to contain and recover oil spilled in the marine environment. In a report resulting from an expert panel examining cumulative impacts of oil development on the North Slope, the National Academies of Science publication concluded that: "no current cleanup methods remove more than a small fraction of oil spilled in marine waters, especially in the presence of broken ice." (NRC 2003)

This message has been repeated in other parts of the world, as well, such as in Norway. A 2006 study examining methods to recover spilled oil in the Barents Sea pointed to the difficulty of operating in ice conditions, citing the usual long distance to infrastructure; increased viscosity of the oil; migration of the oil in the ice; spillage in pools and channels between ice floes, and even under the ice; difficulty in detection and monitoring spills; and other challenges. (Evers, K, Sørheim, KR and Singsaas, I, 2006).

One year ago, in examining the risks of oil development around Sakhalin Island in Russia, World Wildlife released a report called Offshore Oil Spill Response in Dynamic Sea Ice Conditions. (DeCola et al, 2006) The report is co-authored by a petroleum engineer with extensive experience on Alaska's North Slope; an Alaskan biologist with years of experience in the field of environmental compliance and drilling operations in Alaska, and a founding member of the Oil Spill Prevention and Response within the Prince William Sound Regional Citizens Advisory

Council. The report focuses on the Sea of Ohkotsk, an area where dynamic seas and long ice seasons make it in many ways similar to the Chukchi Sea. The bottom line is: **"mechanical recovery is extremely difficult in ice-infested waters; dispersants are an unproven technology; and in-situ burning has not been demonstrated in actual field tests to be effective in ice coverage above 30% or below 70%."** Where ice concentration exceeds 70%, the ice may provide natural containment, although the sea ice may transport oil great distances so that it is unavailable for response once spring break up occurs. At higher ice concentrations, significant logistical, technical, and safety challenges remain in tracking, assessing, and igniting the oil slicks and recovering burn residues."

Recently, the lack of capacity to respond to and contain spills has been quite evident, even highly developed, technologically sophisticated nations. For example, just last month in the North Sea, a large oil spill occurred in the cold waters of the North Sea, resulting in what may be the second largest spill in Norway's history. The incident occurred during the transfer of crude oil from a loading buoy to a tanker near an offshore oil platform known as Statfjord A and resulted in 4,000 cubic meters being spilled into the sea.

D. Other Concerns: Is the Race for Oil Leading to "Shortcuts" at the Expense of Our Environment?

As noted above, in pursuing the Chukchi Lease Sale 193, MMS disregarded expert opinions of other US agencies. In the past week, information released by the Public Employees for Environmental Responsibility (PEER) points out that MMS has also ignored the advice of its own experts in Alaska in its effort to expedite the permitting processes necessary to conduct lease sales. The agency ignored strong cautions of one biologist who warned about the potential for the introduction of invasive species into Alaskan waters by exploration activities. Rather, the agency "directed its scientists to exclude any assessments of the high likelihood that offshore oil drilling would introduce invasive species into Arctic waters."

"While MMS contends that it has done complete environmental assessments of its Arctic offshore drilling permits, its own specialists – many of whom have left in recent months – vehemently disagree. After he was removed from any role on invasive species issues and his work on native fish populations was altered, [the employee] resigned from MMS in disgust. In addition, MMS chose to ignore state and federal experts who seconded the warnings from MMS staff scientists." (PEER press release).

As the MMS Five Year Program unfolds in Alaska and throughout the US, such reports of internal pressure to expedited development at the cost of the best available science are alarming and must be further investigated.

III. Summary

World Wildlife Fund appreciates the efforts of this Committee and Congress more generally to investigate current and future protections for the polar bear.

In closing, I would like to say that listing this species under the Endangered Species Act is a last resort, and in essence, signifies a failure of policy and management. We have known for some time of dangers of global warming, and should have acted more expediently to address them. Had we done so, perhaps we would not be faced with the need to list this species. Before we are faced with similarly difficult decisions for other species, we should enact legislation directly dealing with global warming, such as policies that will require the energy sector to rapidly and dramatically reduce CO2 emissions. In the short term, we need to closely scrutinize and prevent all actions that may add further stress to the polar bear, including conducting oil and gas leasing in prime polar bear habitat.

Finally to summarize the points in this testimony:

- The overwhelming body of peer-reviewed science regarding the relationship of declining Arctic sea ice to declines in polar bear populations meets the statutory criteria requiring a listing as threatened under the Endangered Species Act.
- While listing the polar bear would be a very important step, the US will have to also take dramatic steps to decrease CO2 emissions, the source of global warming that is melting polar bear habitat and transforming the Arctic.
- The US has an obligation to heed the science and to uphold its international commitments to protect polar bears and their habitat.
- The US has only two polar bear populations, inhabiting the Beaufort and Chukchi Sea. We must reduce all known sources of stress to these populations, including offshore oil and gas development.
- Global experience tells us that the technology to effectively contain and clean up such spills does not exist at this time and the risks to marine life posed by offshore oil and gas development are too great.
- We must do everything possible to allow for the polar bear to persist, and to leave future generations of Americans with a chance of knowing that polar bears and other Arctic wildlife exist in the wild. Listing the polar bear will be the first step in the right direction.

Thank you for your consideration.

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Attachments

Facts and Fallacies about Polar Bears: Polar Bear Listing – Dispelling Fallacies with Facts

WWF Comments to the Fish and Wildlife Service on the Proposed Listing of the Polar Bear April 10, 2006

WWF Comments to the Fish and Wildlife Service on the Proposed Listing of the Polar Bear April 1, 2007

WWF Comments to the Fish and Wildlife Service on the Proposed Listing of the Polar Bear October 22, 2007 [Comment Period Reopened]

1965 USFWS Press Release: "Five-Nation Conference on Polar Bears Scheduled for September in Alaska"

WWF

October 22, 2007

Dr. Rosa Meehan
Supervisor
U.S. Fish and Wildlife Service
Marine Mammals Management Office
1011 East Tudor Road
Anchorage, AK 99503

Attn: Polar Bear Finding

Dear Dr. Meehan:

World Wildlife Fund (WWF) appreciates the opportunity to comment on the recently published U.S. Geological Survey (USGS) reports which present a comprehensive analysis of the world's polar bear (*Ursus maritimus*) population status and threats. WWF understands that these scientific reports will be used by the U.S. Fish and Wildlife Service (Service) in conjunction with other information gathered in the process to make a final decision on whether to protect the polar bear as a "threatened" species under the Endangered Species Act.

In the previous comment period on this subject, WWF supported the listing of this species as Threatened. Now, based on the rigorous and in-depth set of analyses provided by USGS, we feel there is even more compelling evidence to make such a decision. The stark conclusion of the USGS research reports is that *"projected changes in future sea ice conditions, if realized, will result in loss of approximately 2/3 of the world's current polar bear population by the mid 21st century. Because the observed trajectory of Arctic sea ice decline appears to be underestimated by currently available models, this assessment of future polar bear status may be conservative."*

The plain facts in these USGS research reports speak for themselves in favor of a listing. The reports' 18 key findings point out that:

- Arctic sea ice decline is likely underestimated by the available models;
- It is now possible to relate declines in the availability of sea ice to declines in metrics of population status for two subpopulations of polar bears (including the Southern Beaufort Sea [SBS] subpopulation inhabiting Arctic Alaska);
- Under a range of future sea ice scenarios for the 21st century, and modeling approaches, the SBS subpopulation of polar bears is projected to decline severely by the end of the century, and in many scenarios, by the mid-century;

- Optimal habitat in the polar basin declined between 1985 and 2006 based on the observational record of sea ice, and the most pronounced polar bear habitat loss in the past decade has occurred in the Chukchi Sea and Barents/Greenland Seas;
- The USGS has projected losses of polar bear habitat within the polar basin to be greatest for peripheral seas of the polar basin (e.g., the Chukchi Sea and Barents Sea);
- The largest reductions in habitat in the polar basin are predicted for spring and summer;
- The USGS projects a 42% loss of optimal polar bear habitat during summer in the polar basin by mid century;
- Polar bears could be extirpated in the divergent ice ecoregion (including Arctic Alaska) within 75 years assuming that sea ice decline follows the mean trajectory predicted by the 10 models used by USGS in their analysis;
- Polar bears could be extirpated in the same ecoregion within 45 years, if sea ice decline follows the minimum trajectory prediction.
- Using the carrying capacity model, the USGS projected populations of polar bears in all other ecoregions to decline at all time steps, with severity of decline dependent upon whether minimum, maximum or mean ice projections were used;
- The USGS forecasts the extirpation of polar bear populations in the seasonal sea ice and polar basin divergent ecoregions (including Arctic Alaska) by 45 years from the present (based on a first-generation Bayesian Network model);
- Polar bear populations in the polar basin convergent ecoregion are forecasted by the USGS to be extirpated 75 years from the present; and
- The USGS specifically notes that sea ice conditions would have to be substantially better than even the most conservative GCM projections to result in qualitatively different outcomes for polar bears in any of the ecoregions.

The federal ESA requires the protection of a species as "Threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." [16 U.S.C. § 1532(20)]. A species is considered "endangered" when it "is in danger of extinction throughout all or a significant portion of its range." [16 U.S.C. §15320(6)].

The USGS science reports represent the best available science and unambiguously show that the polar bear is threatened with extinction in the foreseeable future chiefly due to ongoing climate warming in the Arctic. WWF strongly believes that the current situation for polar bears clearly relates to ESA Section 4(a)(1) and therefore supports formal listing and protection measures for the polar bear as a Threatened species under the ESA.

Thank you for your consideration.
Sincerely,

Margaret D Wh

Margaret Williams
Director, Kamchatka/ Bering Sea ecoregion Program

WWF

April 1, 2007

Rosa Meehan
Supervisor, Marine Mammals Management
U.S. Fish and Wildlife Service
Marine Mammals Management Office
1011 East Tudor Road
Anchorage, AK 99503

Attn: Polar Bear Finding

Dear Ms. Meehan:

On behalf of the World Wildlife Fund, thank you for this opportunity to comment on the recommendation by the U.S. Fish and Wildlife Service to list the polar bear (*Ursus maritimus*) as "Threatened" under the U.S. Endangered Species Act (ESA).

WWF is an international conservation organization with 1.2 million members in the US. WWF works around the world, including in all of the Arctic countries inhabited by polar bears. One of our priority ecoregions is the Bering Sea, where we have been actively involved in conservation of the Alaska-Chukotka polar bear population.

Last year, WWF strongly supported formal listing and protection measures for the polar bear as a Threatened species under the ESA, for reasons outlined herein and with the support of the best available science. Our position has not changed. In fact, additional data pointing to climate change impacts on the Arctic sea ice only further reaffirm the conclusions that listing is warranted.

The federal ESA requires the protection of a species as "Threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." [16 U.S.C. § 1532(20)]. A species is considered "endangered" when it "is in danger of extinction throughout all or a significant portion of its range." [16 U.S.C. §15320(6)]. The factors that are used to determine whether a species is threatened or endangered are enumerated in Section 4(a)(1) of the Act (16 U.S.C. § 1533(a)(1)(A)-(E)). Of the five factors listed in that section, three weigh most heavily in determining the status of polar bears:

A. the present or threatened destruction, modification or curtailment of its habitat or range;
D. the inadequacy of existing regulatory mechanisms; and
E. other natural or manmade factors affecting its continued existence.

WWF believes that polar bears in the U.S. meet the statutory criteria cited above for protection as Threatened under the ESA, based on the now substantial and growing body of peer-reviewed and published scientific data (discussed below) and the numerous observations of Arctic community members (i.e. Local & Traditional Knowledge). These sources strongly suggest that current and projected global warming is and will continue to negatively and severely impact polar bears' habitat, prey, behavior, reproduction, and survival such that the species faces probable dramatic population declines by the end of this century.

Finally, WWF fully endorses precautionary and proactive conservation principles and argues for application of strong protective measures for this species sooner rather than later, as the observed rate of Arctic ecosystem change (especially reductions in sea ice cover, extent, and duration) is accelerating well beyond that projected by early climate models.

Evidence[1] that the polar bear warrants listing in under the ESA as "Threatened", and that fulfill the listing criteria that the species "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" according to 16 U.S.C. § 1532(20), include:

1. Climate Impacts on Polar Bear Habitat

The most fundamental characteristic of polar bears in relation to their ecology is their strong affinity for sea ice (Derocher et al. 2004). Polar bears are almost completely dependent on sea ice for sustenance. Their preferred habitat is the annual sea ice over the continental shelf and inter-island archipelagos that encircle the polar basin. Polar bears depend on ice for hunting and feeding on the seals that use the ice as a platform for parturition and lactation, and for hauling out to rest and molt (Iverson et al. 2006; see also Ferguson et al. 1998, 2000). Iverson et al. (2006) further state:

> Those bears that live on the pack ice all year round, such as in the Beaufort Sea, move north with the receding floe edge in summer and south again in winter

[1] Scientific data are better for some regions/populations than for others. However, remote sensing has allowed more homogenous high quality data to be compiled across the Arctic marine ecosystem; these data include crucial sea-ice habitat data and projections relating to polar bear survival prospects across the entire species range.

> (citing Amstrup et al. 2000). The southernmost populations live year-round in the Hudson and James bays, Canada, where ice is completely absent for at least 4 months during summer and autumn each year, and all bears are forced ashore to fast until freeze-up, while pregnant females fast for 8 months (citing Stirling et al. 1977, Ramsay and Stirling 1988). Thus the presence of sea-ice is critical to polar bears and changes in its distribution and duration will have a profound impact on their foraging patterns and population ecology (citing Stirling and Derocher 1993, Stirling et al. 1999).

Derocher et al. (2004) similarly note that anything that significantly changes the distribution, abundance or existence of sea ice will have profound effects on the persistence of polar bears.. Such habitat loss or fragmentation is well documented to be a primary cause of extinctions (Beissinger 2000, Ceballos and Ehrlich 2002).

Climate changes appear to threaten the sea ice itself - the floating platform upon which polar bears depend for nearly all of their life history needs (Amstrup 2006). Experts agree that the Arctic Region is undergoing an unprecedented and accelerating warming trend (Serreze et al 2000; Parkinson and Cavalieri 2002; Comiso 2002a, 2002b, 2003; ACIA 2004; IPCC 2007), shifting from arctic to subarctic conditions, in some cases profoundly altering the fundamental biological components that are usually associated with the Arctic realm (e.g. Grebmeier et al. 2006). This consensus confirms what has been known for some time by Native peoples inhabiting this region (e.g. ACIA 2004, WWF *Climate Witness Program* testimony www.panda.org/arctic).

Acrtic sea ice is melting at an unprecedented rate as a result of increased global temperatures, very likely caused by anthropogenically based atmospheric pollution accumulating since 1750 (IPCC, 2007) (Meier et al. 2005, NSIDC 2005, Overpeck et al. 2005, Stroeve 2005). Scientists estimate that in just the last three decades, the average annual sea ice extent has decreased by nearly 1.3 million square kilometers or 500,000 square miles (twice the size of Texas), at a rate of about 8-9% per decade (Comiso 2002b, NSIDC 2005). It appears that the warming/ melting trend is accelerating (ACIA 2004, NSIDC 2005). Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850) (IPCC 2007). Current predictions in the scientific literature are that, by the end of this century, annual temperatures in the Arctic will likely rise by 7 degrees C (13.6 degrees F) over oceans (ACIA 2004) and that summer Arctic sea ice might decline by 50-100% (ACIA 2004, Comiso 2003, Gough and Wolfe 2001, NSIDC 2005, Overpeck et al. 2005).

The latest satellite information from the National Snow and Ice Data Center and NASA indicates that the observed temperature increases and ice declines are not anomalies but signal a new and ominous trend: 2005 marked the fourth consecutive year exhibiting the lowest amount of ice cover in more than a century. Mean temperatures in 2001-2005 were 20% warmer than the average of 1978-2000 and the winter recovery of sea ice in 2004-2005 was the smallest on satellite record. These organizations concluded that Arctic sea ice, home to all polar bears on Earth, "is likely on an accelerating, long-term decline" (NSIDC 2005).

During most seasons polar bears prefer mixed ice habitats near ice edges in shallow waters over the continental shelf (Durner et al. 2006b). In past decades, this habitat use pattern was maintained during summer because of persistent near shore ice. The summer distribution of polar bears, however, has changed in recent years because of extensive ice melt that forces most polar bears to summer in deep water ice habitat > 200 km from the mainland coast while a smaller segment of the population is forced to use shoreline habitat.

Further evidence of climate change impact upon polar bear habitat is manifest in a landward shift in polar bear denning. Polar bears in the northern Alaska region den in coastal areas and on offshore drifting pack ice. Fischback et al. (2006) reported find that the proportion of dens on pack ice between 137° W and 167° W longitude declined from 62% in 1985-1994 to 37% in 1998-2004. Fischback et al. (2006) hypothesize that this landward shift was a response to reductions in stable old ice, increases in unconsolidated ice, and lengthening of the melt season, which have likely reduced the availability and quality of pack ice denning habitat. They note that if these sea ice trends continue, as predicted , they expect the proportion of polar bears denning on coastal habitats will continue to increase, until such time as the autumn ice retreat precludes offshore pregnant females from reaching the Alaska coast in advance of denning. One must then ask, how might climate change alter coastal landscapes and terrestrial denning habitat, particularly in light of ACIA (2004) predictions of rising sea levels, rising river flows, declining snow cover, and thawing permafrost, and then how might such habitat alterations influence polar bear reproduction, survival, and population dynamics.

2. Climate Impacts on Polar Bear Prey

Sea ice also is the preferred habitat for polar bears' main prey: ringed and bearded seals (Smith 1980). Polar bears are specialists on these phocid seals, though sometimes opportunistically taking other prey, like walrus or small whales, (e.g., Derocher et al. 2002).

Recently, Iverson et al (2006) reported on their study examining polar bear diets, where they used quantitative fatty acid signature analysis of polar bear adipose tissue to estimate their diets in the 1980s-1990s across three major regions of the Canadian Arctic. Their result show that polar bears consumed ringed and bearded seals throughout their range, however, diets differed greatly among regions. Other species shown to be substantive in the diet of sampled polar bear populations include harp and hooded seals, and walrus, depending on region. Changes in diet were also associated with environmental variation (e.g., periodicity of ice breakup). Polar bear diets also varied spatially within a subpopulation as a function of latitude.

Of concern is how accessible prey will be as sea ice diminishes in the Arctic region. Rosing-Avid (2006) studied and modeled the short- and medium-term effects of climate change on mortality of ringed seal pups and polar bear cubs off east Greenland. Iverson et al. (2006) noted that during the 1990s in the western Hudson Bay, the trend towards progressively earlier sea ice breakup dates was accompanied by significant decreases in ringed seals in polar bear diets....and that all species [of ice seals] are mainly only available to bears on the ice so these changes in diet, especially reduction in ringed seals, compliment evidence that during the same period bears came ashore earlier and in progressively poorer condition, with a decline in both physical and reproductive characteristics (Iverson et al. 2006 citing Stirling et al. 1999).

The emerging warmer climate regime is likely to negatively affect polar bears in two ways: (1) by reducing the duration, thickness, and extent of available ice platforms used for hunting (as described above); and (2) by reducing populations of ringed and bearded seals, which, like polar bears, are dependent on, and sensitive to, perturbations to sea ice habitat and related changes in primary productivity (Derocher et al. 2004). Winter and spring distribution of ringed seals reflects the general distribution of polar bears. During summer, while some ringed seals may track the ice edge as it retreats north, others may have an open water life style and thus would be unavailable to polar bears. Bearded seals, due to their benthic feeding habits, have not been available to polar bears during recent summers. Changes in ice characteristics have been documented to have a significant negative effect on population size and recruitment of ringed seals (Ferguson et al. 2005) and subsequently of polar bears (Stirling 2002). Thus, predicted and observed changes in the distribution, characteristics, and timing of sea ice certainly have the potential to profoundly and negatively affect the ice-associated species at the population level (Stirling and Derocher 1993, Derocher et al. 2004).

3. Climate Impacts on Polar Bear Reproduction and Survival

Changes to ice habitats also affect polar bear denning opportunities, ultimately reducing population reproductive success. For pregnant bears that den on land, ice must freeze early enough in the fall to allow them to walk or swim to the coast. As the distance from the ice edge to the coast increases, it will become progressively more difficult for them to reach their preferred locations (Derocher et al. 2004). For females that den on multiyear ice rather than stable land, increased drift rates of this habitat could mean longer distances to travel with new cubs to reach the core of their normal home range (Derocher et al. 2004).

Such increased energy expenditure by individual polar bears could result in both lower survival and reproductive rates in the long term (Derocher et al. 2004) by reducing stores of adipose tissue, thereby impacting body condition. Much of the life history of polar bears, particularly reproductive females, is tied to storing large quantities of adipose tissue when hunting conditions are favorable and subsequently using these stores when conditions do not allow for hunting (Ramsay and Stirling 1988), such as during the four-month fast that occurs in many populations during summer when sea ice is in retreat. Warming trends will force polar bears to come ashore earlier in the season, which means that they will have less opportunity to store fat, with the potential to decrease polar bear survival, depending on life stage and condition (e.g., Regehr et al. 2006b). Adult female polar bears lose approximately 4.71 kg/day during fasts (the rate may be 4-fold higher for pregnant females; Derocher and Stirling 1995). Because females apparently cannot reproduce when they drop below 189 kg, and at current rates of ice decline, it has been calculated that most females in the southerly Hudson Bay population will be unable to reproduce as soon as 2012 (Derocher et al 1992). Compromised females will also likely produce fewer, smaller cubs with lower survival rates (Derocher and Stirling 1996, Derocher and Stirling 1998).

Regehr et al. (2006a) examined cub production between the early (1967–89) and latter (1990–2006) time periods and found evidence of a decrease in the survival of polar bear cubs of the Southern Beaufort Sea population during their first 6 months of life. For polar bears captured during the autumn, the number of cubs of the year per adult female declined significantly from a mean of 0.61 in the early period to a mean of 0.25 in the latter period. This decline can only be explained by lower survival of cubs after den emergence. In contrast to the autumn data, the numbers of cubs of the year per adult female captured in the spring increased between the two periods. This reflects a shortened inter-birth interval for the recent period. Apparently, more females are losing their cubs shortly after den emergence, breeding again shortly after losing their cubs, denning again the following autumn, and emerging with another litter the following spring. In short, numerous cubs are currently being born in the Southern Beaufort Sea region, but many of them are not being recruited into the population (Regehr et al., 2006a).

Reduced hunting success as a result of compromised habitat integrity will likely result in reduced fat stores because of the increased energy output associated with traveling on more labile ice or swimming across open water for longer distances when ice retreats (Mauritzen et al 2003). If ice conditions are particularly poor, cub mortality may increase as they are forced to swim greater distances in cold water (Derocher et al 2004). Adult mortality can also result from changes in ice condition, timing, and extent: recently, there have been documented accounts of adult polar bears drowning in the Alaskan Beaufort Sea, and scientists suggest that mortalities due to offshore swimming during late-ice (or mild ice) years may be an important and unaccounted source of natural mortality given energetic demands placed on individual bears engaged in long-distance swimming (Monnett and Gleason 2006). Also suggested is that drowning-related deaths of polar bears may increase in the future if the observed trend of regression of pack ice and/or longer open water periods continues [as climate models project]. Increased adult mortality has also been observed in recent years on Wrangel Island in the Chukchi Sea, home (with nearby Herald Island) to 80% of the region's breeding female polar bears. In 2002, a year of exceptionally early ice retreat, the Island's resident polar bear biologist reported the highest proportion of skinny bears ever and a very high mortality rate (Ovsyanikov 2003) .

Case Study: Southwestern Hudson Bay Population

In southwestern Hudson Bay, increasing temperatures have already increased the duration of the ice-free period (thus increasing the fast) by approximately 2.5 weeks (Stirling et al. 1999). A recent study of this well-known population, which alone constitutes roughly 5-10% of the total estimated world population, has established, for the first time, a negative population-level effect of climate change on polar bears (Regehr et al. 2005). The study documented that the size of this population had declined from approximately 1200 bears in 1987 to fewer than 950 bears in 2004. The authors also established a statistical correlation between earlier summer ice break-up and decreased survival for all but prime-aged bears.

It is widely recognized, based on sea ice remote sensing and oceanographic monitoring, that similar rapid reductions of sea ice (and hence polar bear feeding and denning opportunities) are probably affecting other populations (such as the Alaska-Russia population), although these have not been as intensely studied as those in southwest Hudson Bay.

4. Threats to Polar Bears Due to Their Life History and Distribution

Polar bears are a classic K-selected species, exhibiting delayed maturation, small litters, and high adult survival rates (Bunnell and Tait 1981). Potential extinction risk for polar bears is heightened because of these characteristic features of their life history, and other traits such as their specialized diet, large body size, long life span, and low genetic diversity (McKinney 1997, Beissinger 2000). Also, because of their long generation time (mean 12-17 years in most regions), polar bears are not well suited to rapid evolution and therefore are unlikely to adapt successfully to the rapidly changing climate and the related effects on habitat and prey.

5. Other Threats to Polar Bears

The existence of polar bears is further threatened by a number of other factors, many of which are likely to be exacerbated by the effects of climate change.

a. Oil and Gas Development and Transport
Active oil and gas exploration, extraction, and transportation occur throughout the range of the polar bear and projected to increase. Polar bears are sensitive to oiling in the event of a spill (Stirling 1990), and their behaviors can be affected by disturbances related to hydrocarbon development (such as seismic blasting and infrastructure development; Derocher et al. 1998). Currently proposed offshore extraction activities pose the greatest threat to polar bears, especially if a spill occurred near a polar bear denning site (Isaksen et al 1998). Also, spills in frozen or partially frozen Arctic waters are hard to detect and no method has proven effective for clean up in this environment. Finally, should climate warming lead to an open northern shipping route, the threat of a spill would be presented to more northerly polar bear populations, such as Alaska's bears in the Chukchi Sea.

b. Pollutants and Disease
Many persistent organic pollutants, such as heavy metals, radioactive elements, and persistent organic pollutants, can reach high levels in polar bears due to their high fat diet and high trophic position (Norstrom et al 1998). Studies have demonstrated that such

chemicals can negatively impact endocrine function (Skaare et al. 2001), immune function (Bernhoft et al 2000), and subsequent reproductive success (Derocher et al. 2003). It is possible that endocrine disrupting chemicals affect behavior and cognitive abilities in polar bears such that they are less able to cope with changes in ice-coverage caused by climate change (Jenssen 2006). Also, environmental pollutants can cause pseudohermaphroditism in female bears, as has been observed in Svalbard (Wiig et al 1998) further reducing population reproductive rates.

Immune compromised, not to mention hungry, bears may be more susceptible to disease or parasites. A study of free ranging populations of polar bears in northern Alaska has been initiated to establish clinical (health) baseline data in order to monitor potential change in health status, using multiple hematologic endpoints and infectious agents exposure measures (Kirk et al. 2006). A relatively high prevalence of serum antibodies to four morbilliviral species [canine distemper (CDV), dolphin morbillivirus (DMV), phocine distemper (PDV), and porpoise morbillivirus (PMV)] were identified. This group of viruses can cause significant disease and mortality in populations of some marine mammals as well as interfere with differentiation and specialization of lymphocytes in vitro. Moreover, the northern range expansion of disease organisms and the nearly complete lack of such organisms in polar bears' evolutionary past also make them vulnerable to novel pathogens (Derocher et al. 20004).

c. Increased Aggressive Human-Bear Interactions

It has been predicted that human-bear interactions would increase as a result of climate-induced changes to polar bear habitat (Stirling and Derocher 1993). There is a documented correlation between date of ice break-up in spring and number of "problem" bears reported in some communities (Stirling et al 1999). Churchill and other communities along the western coast of Hudson Bay, Canada have experienced an increase in the number of human-polar bear interactions in recent years (Regehr et al. 2006b). Earlier sea ice breakup is believed to have resulted in a larger number of nutritionally-stressed polar bears, which are encroaching upon human habitations in search of supplemental food. More bears on land, especially if they are hungry, can lead to more attacks on humans and, correspondingly, more "defense of life and property" killings of bears. Just this year, in a remote village on Russia's Chukotka Peninsula, a young woman was killed by an unusually aggressive bear; this was the third reported bear shooting in Russia this winter.

Stirling and Iverson (2006) examined possible effects of climate warming on five populations of polar bears in the Canadian Arctic. Inuit hunters in the areas of four polar bear populations in the eastern Canadian Arctic (including Western Hudson Bay) have reported seeing more bears near settlements during the open-water period in recent years. In a fifth ecologically similar population, no changes have yet been reported by Inuit hunters. These observations, interpreted as evidence of increasing population size, have resulted in increases in hunting quotas. However, long-term data on the population size and body condition of polar bears in Western Hudson Bay, as well as population and harvest data from Baffin Bay, make it clear that those two populations at least are more likely to be declining, not increasing.

While the ecological details vary in the regions occupied by the five different populations examined, analysis of passive-microwave satellite imagery beginning in the late 1970s indicates that the sea ice is breaking up at progressively earlier dates, so that bears must fast for longer periods during the open-water season. Thus, at least part of the explanation for the appearance of more bears near coastal communities and hunting camps is likely that they are searching for alternative food sources in years when their stored body fat depots may be depleted before freeze-up, when they can return to the sea ice to hunt seals again. Stirling and Iverson (2006) hypothesize that, if the climate continues to warm as projected by the Intergovernmental Panel on Climate Change (IPCC), then polar bears in all five populations examined will be increasingly food-stressed, and their numbers are likely to decline eventually, probably significantly so. As these populations decline, problem interactions between bears and humans will likely continue, and possibly increase, as the bears seek alternative food sources.

d. Illegal Harvest of Polar Bears

Harvesting of polar bears has historically been the main threat to the species, but this has been largely mitigated through various management regimes (Prestrud and Stirling 2002). However, in some parts of the bears' range, poaching is still a problem that can have profound effects on population persistence. For example, the unregulated harvest of Chukchi Sea polar bears in Russia appears to be significant and raises concern about the status of this population. Notably, large numbers of polar bear hides have been offered for sale on the internet in Russia. Although it has not been proven that the source of these hides is Chukotka, we do know this population is vulnerable to illegal hunting. Although actual harvest levels are unknown, an estimated 250-300 polar bears were illegally taken on Russia's Chukotka Peninsula in 2002. Experts believe this harvest was at least twice the level experienced in previous years and likely resulted from the large number of bears that were stranded on land by an early ice retreat (Ovsyanikov 2003). A recent population viability analysis indicated that, even at a harvest level of 180 bears/year, there would likely be a 50% reduction in this population (which is shared with the U.S.) size within 18 years (Schliebe 2003).

6. Insufficient Current Protections for Polar Bears Under U.S Legislation.

Currently, polar bears in the U.S. are protected under regulations of the Marine Mammal Protection Act ("MMPA"). The primary focus of this legislation, with respect to polar bears, has been the management and reporting of the limited legal harvest of polar bears by Alaska Natives. The MMPA also sets the conditions for specific activities in polar bear habitats, such as oil and gas exploration, development, and production. The MMPA regulations have led to a marked decline in the harvest of bears in the U.S.; this Act does not address the take from this same population by poachers in Russia, nor does it address habitat loss caused by human-induced climate warming. A "Threatened" listing under ESA corresponds to, and would automatically result in, the listing of polar bears as "Depleted" under MMPA.

A potential form of additional protection for U.S. polar bears will be the "Agreement on the Conservation and Management of the Alaska-Chukotka Polar Bear Population". This treaty was signed by the governments of the U.S. and Russia in October of 2000, but now awaits the reconciliation and passage of implementing legislation by the U.S. Senate Commerce Committee and the House Resources Committee. Under the terms of the Agreement, an international U.S.-Russia Polar Bear Commission (with both federal and native representatives) will be formed to oversee a polar bear conservation program. The primary focus of this Agreement is the regulation of the limited subsistence hunt (e.g. setting harvest limits), which the group will have the authority to enforce as a matter of law. While the group will also address habitat issues related to oil and gas development, shipping, and other human activities, its role in this regard will be consultative and advisory only and will not carry the force of law. The Agreement will not explicitly address the mitigation of threats related to global warming.

Polar Bear Critical Habitat

As part of the request for comments on the proposal to list the species (i.e., polar bear), the Service is also seeking information regarding measures to consider and reasons why any habitat should or should not be determined to be critical habitat for the polar bear if the listing becomes final.

Section III(5)(A)(i) of the Endangered Species Act (ESA) defines "critical habitat" for threatened or endangered species to mean the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of the ESA, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection. Section III(5)(C) specifies that "except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area which can be occupied by the threatened or endangered species."

USFWS states that "the primary threat to polar bears is the decrease of sea ice coverage. Although some females use snow dens on land for birthing cubs, polar bears are almost completely dependent upon sea ice for their sustenance. Any significant changes in the abundance, distribution, or existence of sea ice will have effects on the number and behavior of these animals and their prey" http://alaska.fws.gov/fisheries/mmm/polarbear/issues.htm). As noted throughout WWF's comments in the proceeding pages, this statement is strongly supported by a rigorous body of peer-reviewed science.

Based on this information and on guidance from the ESA, WWF recommends that the critical habitat for polar bears be defined as all Arctic region sea ice capable of supporting a polar bear; all known maternal denning areas; and all of those areas likely to support maternal denning areas on land and sea, based on projected changes in sea ice dynamics.

Sea ice is a physical feature essential to the conservation of polar bears. Schliebe et al. (2006) note that polar bear distributions are not uniform throughout the Arctic, but depend upon the type of sea ice and its location and extent over time, availability of prey, and reproductive status. In their review of the existing information, Schliebe et al. (2006) note that data indicate that population distribution may not be solely a reflection of prey availability, but instead other factors may operate to influence distributions.

The sea ice environment is highly dynamic and follows annual patterns of expansion and contraction (see Schliebe et al. 2006). Movements of sea ice are related to winds, currents, and seasonal temperature fluctuations that promote its formation and degradation. Sea ice is generally categorized by the stage of development, form, concentration, and type of ice and may include stable fast ice with drifts; stable fast ice without drifts; floe edge ice; moving ice; continuous stable pressure ridges; coastal low level pressure ridges; and fiords and bays. Alternatively, sea ice may be characterized as pack ice; shore-fast ice; transition zone ice; and polynyas and leads.

It is evident there are a variety of forms of sea ice for which polar bears may (or may not) show a preference. Schliebe et al. (2006) noted from the scientific literature that predictable sea-ice conditions could help bears in hunting success and sheltering. However, sea ice conditions are not necessarily predictable in all areas, as evident in the fluctuating sea-ice condition in regions like the Beaufort Sea or Baffin Bay, and possibly requiring modifications of foraging strategy from month to month or even day to day during break-up, freeze-up, or periods of strong winds. Given the day-to-day and month-to-month dynamic changes of sea ice forms in the Arctic, and our inability to accurately predict such changes to sea ice forms in the days, weeks, months, years, and decades ahead because of climatic warming in the Arctic, it is prudent to designate all Arctic region sea ice capable of supporting a polar bear as critical habitat.

As noted above, polar bears' life history is intricately linked to the Arctic sea ice. However, it would be impracticable and unrealistic to accurately predict (with the current information) how polar bears will respond to the diminishment of one or several sea ice forms (e.g., stable fast ice with drifts, shore-fast ice) relative to other forms (e.g., coastal low level pressure ridges, transition zone ice) as climatic warming progresses in the Arctic. Thus WWF would caution USFWS against attempting to identify just one or even several forms of sea ice as critical habitat while excluding other sea ice forms also necessary for polar bear survival now or in the future.

Maternal Denning Habitat as Polar Bear Critical Habitat

Throughout their range, most pregnant female polar bears excavate dens in snow located on land in the fall- early winter period with exceptions in Hudson Bay and the southern Beaufort Sea (Schliebe et al. 2006). Successful denning by polar bears requires accumulation of sufficient snow for den construction and maintenance. Adequate and timely snowfall combined with winds to cause snow accumulation leeward of topographic features create denning habitat (Schliebe et al. 2006). Denning areas are both physical and biological features necessary for the conservation of polar bear populations.

The IPCC (2007) notes that snow cover is projected to contract in the decades ahead. Widespread increases in thaw depth are projected over most permafrost regions. Coincident with decreasing snow fall and permafrost thawing, global sea levels are projected to continue rising during the 21st century. Decreased snowfall, permafrost thawing, increased precipitation, and the inundation of Arctic coastal areas due to rising sea level, appear likely to diminish maternal denning sites currently used on land, while at the same time, the current and future loss of sea ice may force a landward shift in maternal denning as observed by Fischback et al. (2006). How future snow melt, permafrost thawing, and rising sea levels in the Arctic might influence maternal polar bear denning habitat appears poorly understood or modeled, but may synergistically interact to form a confluence of factors that collectively diminish maternal denning habitat on Arctic lands and on sea ice. Therefore WWF believes that a prudent measure would be to identify maternal denning areas on sea ice and land as polar bear critical habitat.

Best Scientific Data Available

Section IV (b)(2) of the ESA specifies the basis for critical habitat determinations—the Secretary shall designate critical habitat, and make revisions thereto, under subsection (a)(3) on the basis of the best scientific data available and after taking into consideration the economic impact, the impact on national security, and any other relevant impact, of specifying any particular area as critical habitat. The Secretary may exclude any area from critical habitat if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless he determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned.

Assertions have been made publicly suggesting that polar bears do not strongly depend on sea ice for their sustenance; that polar bears are adaptable to foraging on terrestrial sources of protein (instead of ice seals); and that polar bears can den in earthen tunnels. Such assertions are extrapolations taken from the scientific literature, but are not regarded as being of strong scientific merit or the best scientific information available. It is more likely that such assertions are hype, and intended to mislead policy makers and wildlife administrators from the fundamental task of conserving polar bear populations as climatic warming in the Arctic diminishes their habitat.

The scientific literature reviewed by Schliebe et al. (2006) clearly establishes that Arctic sea ice and maternal denning habitat on land and sea are necessary to maintaining healthy polar bear populations; that reflects the best available science. Furthermore, the IPCC (2007), upon extensive study, debate, and review of the best available science, determined that sea ice is projected to shrink in the Arctic under all IPCC Special Report emission scenarios, and that in some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. Additionally, the IPCC notes that anthropogenic warming and sea level rise will continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilized. The IPCC (2007) and the ACIA (2004, 2005) reflects the best available science on climate change, particularly in the Arctic.

Concurrent Designation of Critical Habitat with Listing Polar Bears

Section 4(a)(3) of the ESA requires that the Secretary, by regulation promulgated in accordance with subsection (b) and to the maximum extent prudent and determinable—

> (A) shall, concurrently with making a determination under paragraph (1) that a species is an endangered species or a threatened species, designate any habitat of such species which is then considered to be critical habitat; and
> (B) may, from time-to-time thereafter as appropriate, revise such designation.

The scientific literature, as well as the professional opinions of many polar bear experts, clearly reflect the critical necessity of sea ice habitat and maternal denning habitat for conservation of healthy polar bear populations. Climatic warming in the Arctic threatens to diminish both sea ice and maternal denning habitats. Therefore, WWF recommends that Arctic sea ice habitat and maternal denning habitat (terrestrial and on sea ice) be designated as polar bear critical habitat concurrently with making a determination under paragraph (i) that the polar bear is an endangered species or a threatened species.

Conclusion

Taylor et al. (2007) assessed scientists' ability to detect declines of marine mammal stocks based on recent levels of survey effort, when the actual decline is precipitous. The percentage of precipitous declines that would *not* be detected as declines was 55% for polar bears/sea otters, given the frequency and precision of recent monitoring effort. This study highlights the need for accurate stock estimates, and the strong likelihood of not accurately detecting declines in polar bear subpopulations. For this reason, WWF recommends listing the polar bear as Threatened. We believe protection under the ESA will benefit and augment conservation of the polar bear as it faces diminishing sea ice habitat due to climatic warming.

The IUCN/Polar Bear Specialist Group concluded that the IUCN Red List classification of the polar bear should be upgraded from "Least Concern" to "Vulnerable" based on the likelihood of an overall decline in the size of the total population of more than 30% within the next 35 to 50 years (Aars et al., 2006). The principal cause of this decline is climatic warming and its consequent negative affects on the sea ice habitat of polar bears. In some areas, contaminants may have an additive negative influence.

The weight of scientific evidence supports the contention that polar bears' habitat is fast disappearing and that predicted individual and population level effects are already occurring. According to Derocher et al. (2004):

> "...polar bears are constrained in that the very existence of their habitat is changing and there is limited scope for a northward shift in distribution. Due to the long generation time of polar bears and the current pace of climate warming, we believe it unlikely that polar bears will be able to respond in an evolutionary sense. Given the complexity of the ecosystem dynamics, predictions are uncertain but we conclude that the future persistence of polar bears is tenuous."

Due to the well-documented and accelerating warming of the Arctic and subsequent loss of polar bear habitat, the potential for such changes to negatively impact polar bear reproduction and survival, and the existing gaps in protection under current polar bear management regulations, WWF supports immediate listing of the polar bear as Threatened under the ESA.

Sincerely,

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Enclosures:

- Literature Cited
- CV for Margaret Williams

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WWF

April 10, 2006

Scott Schliebe
Polar Bear Project Leader
U.S. Fish and Wildlife Service
Marine Mammals Management Office
1011 East Tudor Road
Anchorage, AK 99503

Re: Polar Bear 90-day petition finding

Dear Scott:

On behalf of the World Wildlife Fund, thank you for this opportunity to comment on the recent determination by the U.S. Fish and Wildlife Service that formal listing and protection of the polar bear (*Ursus maritimus*) under the U.S. Endangered Species Act (ESA) may be warranted. WWF is an international conservation organization with 1.2 million members in the US. WWF works around the world, including in all of the Arctic countries inhabited by polar bears. One of our priority ecoregions is the Bering Sea, where we have been actively involved in conservation of the Alaska-Chukotka polar bear population.

WWF strongly supports formal listing and protection measures for the polar bear as a Threatened species under the ESA, for reasons outlined herein and with the support of the best available science.

The federal ESA requires the protection of a species as "Threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." [16 U.S.C. § 1532(20)]. A species is considered "endangered" when it "is in danger of extinction throughout all or a significant portion of its range." [16 U.S.C. §15320(6)]. We believe that the current situation for polar bears clearly relates to ESA Section 4(a)(1). Factors weighted heavily as listing evaluation criteria that apply to polar bears include:

A. the present or threatened destruction, modification or curtailment of its habitat or range;
D. the inadequacy of existing regulatory mechanisms; and
E. other natural or manmade factors affecting its continued existence.
[See Title 6 U.S. Code, Section 1533(a)(1)(A-E)]

WWF believes that polar bears in the U.S. meet the statutory criteria cited above for protection as Threatened under the ESA, based on the now substantial and growing body of peer-reviewed and published scientific data (discussed below) and the numerous observations of Arctic community members (i.e. Local & Traditional Knowledge). These sources strongly suggest that current and projected global warming is and will continue to negatively and severely impact polar bears' habitat, prey, behavior, reproduction, and survival such that the species faces possible global extinction by the end of this century.

Finally, WWF fully endorses precautionary and proactive conservation principles and argues for application of strong protective measures for this species sooner rather than later, as the observed rate of Arctic ecosystem change (especially reductions in sea ice cover, extent, and duration) is accelerating well beyond that projected by early climate models.

Evidence[1] that the polar bear warrants listing in under the ESA as "Threatened", and that fulfill the listing criteria that the species "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" according to 16 U.S.C. § 1532(20), include:

1. <u>Climate Impacts on Polar Bear Habitat</u>

The most fundamental characteristic of polar bears in relation to their ecology is their utter dependence on sea ice habitats (Derocher et al. 2004). Anything that significantly changes the distribution and abundance, let alone the very existence of sea ice will have profound effects on the persistence of polar bears on Earth. Such habitat loss or fragmentation is well documented to be a primary cause of extinctions (Beissinger 2000, Ceballos and Ehrlich 2002).

Experts agree that the once-characteristic ecotype of the far north is undergoing an unprecedented and accelerating warming trend (ACIA 2004, Serreze et al 2000, Parkinson and Cavalieri 2002, Comiso 2002a, 2002b, 2003), shifting from arctic to subarctic conditions, in some cases profoundly altering the fundamental biological components that are usually associated with the Arctic realm (e.g. Grebmeier et al. 2006). This consensus confirms what has been known for some time by Native peoples inhabiting this region (e.g. ACIA 2004, WWF *Climate Witness Program* testimony <u>www.panda.org/arctic</u>).

Because of increased global temperatures thought to result from accumulated atmospheric pollution, Arctic sea ice is melting at an unprecedented rate (Meier et al. 2005, NSIDC 2005,

[1] Scientific data are better for some regions/populations than for others. However, remote sensing has allowed more homogenous high quality data to be compiled across the Arctic marine ecosystem; these data include crucial sea-ice habitat data and projections relating to polar bear survival prospects across the entire species range.

Overpeck et al. 2005, Stroeve 2005). Scientists estimate that in just the last three decades, the average annual sea ice extent has decreased by nearly 1.3 million square kilometers or 500,000 square miles (twice the size of Texas), at a rate of about 8-9% per decade (Comiso 2002b, NSIDC 2005). It appears that the warming/ melting trend is accelerating (ACIA 2004, NSIDC 2005). Current predictions in the primary literature are that, by the end of this century, annual temperatures in the Arctic will likely rise by 7 degrees C (13.6 degrees F) over oceans (ACIA 2004) and that summer Arctic sea ice might decline by 50-100% (ACIA 2004, Comiso 2003, Gough and Wolfe 2001, NSIDC 2005, Overpeck et al. 2005).

The latest satellite information from the National Snow and Ice Data Center and NASA indicates that the observed temperature increases and ice declines are not anomalies but signal a new and ominous trend: 2005 marked the fourth consecutive year exhibiting the lowest amount of ice cover in more than a century. Mean temperatures in 2001-2005 were 20% warmer than the average of 1978-2000 and the winter recovery of sea ice in 2004-2005 was the smallest on satellite record. These organizations concluded that Arctic sea ice, home to all polar bears on Earth, "is likely on an accelerating, long-term decline" (NSIDC 2005).

2. Climate Impacts on Polar Bear Prey

Sea ice also is the preferred habitat for polar bears' main prey: ringed and bearded seals (Smith 1980). Polar bears are specialists on these phocid seals, only rarely and opportunistically taking other prey, like walrus, small whales, or other seals (Derocher et al. 2002). Of concern is how accessible prey species will be in an altered sea ice environment. Sea ice is the physical platform from which polar bears hunt; they only rarely capture prey successfully in open water (Furnell and Oolooyuk 1980). The emerging warmer climate regime is likely to negatively impact polar bears both by reducing the duration, thickness, and extent of available hunting habitat (as described above) and also by reducing populations of these two obligate prey species, which, like polar bears, are sensitive to perturbations in the sea ice environment and related changes in primary productivity (Derocher et al. 2004). In illustration of this, changes in ice characteristics have been documented to have a significant negative effect on population size and recruitment of ringed seals and subsequently of polar bears (Stirling 2002).
Thus, predicted and observed changes in its distribution, characteristics, and timing of sea ice certainly have the potential to profoundly and negatively affect the species at the population level (Stirling and Derocher 1993, Derocher et al. 2004).

3. Climate Impacts on Polar Bear Reproduction and Survival

Changes to ice habitats also affect polar bear denning opportunities, ultimately reducing population reproductive success. For pregnant bears that den on land, ice must freeze early enough in the fall to allow them to walk or swim to the coast. As the distance from ice edge to coasts increases, it will become progressively more difficult for them to reach their preferred locations (Derocher et al. 2004). For females that den on multiyear ice rather than stable land, increased drift rates of this habitat could mean longer distances to travel with new cubs to reach the core of their normal home range (Derocher et al. 2004).

Such increased energy expenditure by individual polar bears could result in both lower survival and reproductive rates in the long term (Derocher et al. 2004) by reducing stores of adipose tissue, thereby impacting body condition. Much of the life history of polar bears, particularly reproductive females, is tied to storing large quantities of adipose tissue when hunting conditions are favorable and subsequently using these stores when conditions do not allow for hunting (Ramsay and Stirling 1988), such as during the 4-month fast that occurs in many populations during summer when sea ice is in retreat. The earlier bears are forced to come ashore, the less fat they have been able to store. Adult female polar bears lose approximately 4.71 kg/day during fasts (the rate may be 4-fold higher for pregnant females; Derocher and Stirling 1995). Because females apparently cannot reproduce when they drop below 189 kg, and at current rates of ice decline, it has been calculated that most females in the southerly Hudson Bay population will be unable to reproduce as soon as 2012 (Derocher et al 1992). Compromised females will also likely produce fewer, smaller cubs with lower survival rates (Derocher and Stirling 1996, Derocher and Stirling 1998).

Reduced hunting success as a result of compromised habitat integrity will likely result in reduced fat stores because of the increased energy output associated with traveling on more labile ice or swimming across open water for longer distances when ice retreats (Mauritzen et al 2003). If ice conditions are particularly poor, cub mortality may increase as they are forced to swim greater distances in cold water (Derocher et al 2004). Adult mortality can also result from changes in ice condition, timing, and extent: recently, there have been documented accounts of adult polar bears drowning in the Alaskan Beaufort Sea, presumably while swimming unusually long distances across open water in unusually rough weather (Monnett et al. 2005); the authors suggest that such drowning events may increase in the future, as ice continues to melt. Increased adult mortality has also been observed in recent years on Wrangel Island in the Chukchi Sea, home (with nearby Herald Island) to 80% of the region's breeding female polar bears. In 2002, a year of exceptionally early ice retreat, the Island's resident polar bear biologist reported the highest proportion of skinny bears ever and a very high mortality rate (Ovsyanikov 2003) .

Case Study: Southwestern Hudson Bay Population

In southwestern Hudson Bay, increasing temperatures have already increased the duration of the ice-free period (thus increasing the fast) by approximately 2.5 weeks (Stirling et al. 1999). A recent study of this well-known population, which alone constitutes roughly 5-10% of the total estimated world population, has established, for the first time, a negative population-level effect of climate change on polar bears (Regehr et al. 2005). The study documented that the size of this population had declined from approximately 1200 bears in 1987 to fewer than 950 bears in 2004.

The authors also established a statistical correlation between earlier summer ice break-up and decreased survival for all but prime-aged bears.

Some experts believe that, at the current rate of decline and unless climate change trends and impacts are swiftly reversed, this self-sustaining population of wild polar bears could become extirpated by 2050 (i.e., only 3 polar bear generations from now – using the IUCN-recognized range for polar bear mean generation time of 12-17 years). It is widely recognized, based on sea ice remote sensing and oceanographic monitoring, that similar rapid reductions of sea ice (and hence polar bear feeding and denning opportunities) are probably affecting other populations (such as the Alaska-Russia population), although these have not been as intensely studied as those in southwest Hudson Bay.

4. Threats to Polar Bears Due to Their Life History and Distribution

Polar bears are a classic K-selected species, exhibiting delayed maturation, small litters, and high adult survival rates (Bunnell and Tait 1981). Potential extinction risk for polar bears is heightened because of these characteristic features of their life history, and other traits such as their specialized diet, large body size, long life span, and low genetic diversity (McKinney 1997, Beissinger 2000). Also, because of their long generation time (mean 12-17 years in most regions), polar bears are not well suited to rapid evolution and therefore are unlikely to adapt successfully to the rapidly changing climate and the related effects on habitat and prey. Finally, although polar bears occupy virtually all available sea ice habitats throughout the vast circumpolar Arctic and number between 21,500-25,000 individuals worldwide (the IUCN/SSC Polar Bear Specialist Group recognizes 20 distinct subpopulations), the species is nevertheless vulnerable to the effects of disappearing and/or fragmented habitat because it occupies a range that, with few exceptions, cannot simply expand further north.

5. Other Threats to Polar Bears

The existence of polar bears is further threatened by a number of other factors, many of which are likely to be exacerbated by the effects of climate change.

a. Oil and Gas Development and Transport
Active oil and gas exploration, extraction, and transportation occur throughout the range of the polar bear. Polar bears are sensitive to oiling in the event of a spill (Stirling 1990), and their behaviors can be affected by disturbances related to hydrocarbon development (such as seismic blasting and infrastructure development; Derocher et al. 1998). Currently proposed offshore extraction activities pose the greatest threat to polar bears, especially if a spill occurred near a polar bear denning site (Isaksen et al 1998). Also, spills in frozen or partially frozen Arctic waters are hard to detect and no method has proven effective for clean up in this environment. Finally, should climate warming lead to an open northern shipping route, the threat of a spill would be presented to more northerly polar bear populations, such as Alaska's bears in the Chukchi Sea.

b. Pollutants and Disease

Many persistent organic pollutants, such as heavy metals, radioactive elements, and persistent organic pollutants, can reach high levels in polar bears due to their high fat diet and high trophic position (Norstrom et al 1998). Studies have demonstrated that such chemicals can negatively impact endocrine function (Skaare et al. 2001), immune function (Bernhoft et al 2000), and subsequent reproductive success (Derocher et al. 2003). Immune compromised, not to mention hungry, bears may be more susceptible to disease or parasites. The northern expansion if range of disease organisms and the nearly complete lack of such organisms in polar bears' evolutionary past also make them vulnerable to novel pathogens (Derocher et al. 20004). Finally, environmental pollutants can cause pseudohermaphroditism in female bears, as has been observed in Svalbard (Wiig et al 1998) further reducing population reproductive rates.

c. Increased Aggressive Human-Bear Interactions

It has been predicted that human-bear interactions would increase as a result of climate-induced changes to polar bear habitat (Stirling and Derocher 1993). There is a documented correlation between date of ice break-up in spring and number of "problem" bears reported in some communities (Stirling et al 1999). More bears on land, especially if they are hungry, can lead to more attacks on humans and, correspondingly, more "defense of life and property" killings of bears. Just this year, in a remote village on Russia's Chukotka Peninsula, a young woman was killed by an unusually aggressive bear; this was the third reported bear shooting in Russia this winter.

d. Illegal Harvest of Polar Bears

Harvesting of polar bears has historically been the main threat to the species, but this has been largely mitigated through various management regimes (Prestrud and Stirling 2002). However, in some parts of the bears' range, poaching is still a problem that can have profound effects on population persistence. For example, the unregulated harvest of Chukchi Sea polar bears in Russia appears to be significant and raises concern about the status of this population. Notably, large numbers of polar bear hides have been offered for sale on the internet in Russia. Although it has not been proven that the source of these hides is Chukotka, we do know this population is vulnerable to illegal hunting. Although actual harvest levels are unknown, an estimated 250-300 polar bears were illegally taken on Russia's Chukotka Peninsula in 2002. Experts believe this harvest was at least twice the level experienced in previous years and likely resulted from the large number of bears that were stranded on land by an early ice retreat (Ovsyanikov 2003). A recent population viability analysis indicated that, even at a harvest level of 180 bears/year, there would likely be a 50% reduction in this population (which is shared with the U.S.) size within 18 years (Schliebe 2003).

6. Insufficient Current Protections for Polar Bears Under U.S Legislation.

Currently, polar bears in the U.S. are protected under regulations of the Marine Mammal Protection Act ("MMPA"). The primary focus of this legislation, with respect to polar bears, has been the management and reporting of the limited legal harvest of polar bears by Alaska Natives. The MMPA also sets the conditions for specific activities in polar bear habitats, such as oil and gas exploration, development, and production. The MMPA regulations have led to a marked decline in the harvest of bears in the U.S.; this Act does not address the take from this same population by poachers in Russia, nor does it address habitat loss caused by human-induced climate warming. A "Threatened" listing under ESA corresponds to and would automatically result in the listing of polar bears as "Depleted" under MMPA.

A potential form of additional protection for U.S. polar bears will be the "Agreement on the Conservation and Management of the Alaska-Chukotka Polar Bear Population". This treaty was signed by the governments of the U.S. and Russia in October of 2000, but now awaits the reconciliation and passage of implementing legislation by the U.S. Senate Commerce Committee and the House Resources Committee. Under the terms of the Agreement, an international U.S.-Russia Polar Bear Commission (with both federal and native representatives) will be formed to oversee a polar bear conservation program. The primary focus of this Agreement is the regulation of the limited subsistence hunt (e.g. setting harvest limits), which the group will have the authority to enforce as a matter of law. While the group will also address habitat issues related to oil and gas development, shipping, and other human activities, its role in this regard will be consultative and advisory only and will not carry the force of law. The Agreement will not explicitly address the mitigation of threats related to global warming.

Conclusion

In light of the documented uncertainties in the face of a warming Arctic, in 2005, the IUCN/SSC Polar Bear Specialist Group concluded that the IUCN Red List classification of tbe polar bear should be upgraded from "Least Concern" to "Vulnerable". These experts based their reclassification on their projection for a 30% overall decline in the size of the total population within the next 35 to 50 years. The principal cause of this decline, according to their own experts, is climatic warming and its consequent negative affects on the sea ice habitat of polar bears.

The weight of scientific evidence supports the contention that polar bears' habitat is fast disappearing and that predicted individual and population level effects are already occurring. According to Derocher et al. (2004):

> "...polar bears are constrained in that the very existence of their habitat is changing and there is limited scope for a northward shift in distribution. Due to the long generation time of polar bears and the current pace of climate warming, we believe it unlikely that polar bears will be able to respond in an evolutionary sense. Given the complexity of the ecosystem dynamics, predictions are uncertain but we conclude that the future persistence of polar bears is tenuous."

Due to the well-documented and accelerating warming of the Arctic and subsequent loss of polar bear habitat, the potential for such changes to negatively impact polar bear reproduction and survival, and the existing gaps in protection under current polar bear management regulations, WWF supports immediate listing of the polar bear as Threatened under the ESA.

Sincerely,

Margaret D. Williams
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World Wildlife Fund

Lara J. Hansen, Ph.D.
Chief Scientist, Climate Change Program
World Wildlife Fund

Enclosures:
CV for Margaret Williams
CV for Lara Hansen
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Senator BOXER. Thank you so much, Margaret. You were right on target, you made all your points. Very good.

I am happy to call on Richard Glenn, an Arctic resident, Alaskan Arctic resident and a sea ice geologist. Welcome, sir.

STATEMENT OF RICHARD GLENN, ALASKAN ARCTIC RESIDENT, SEA ICE GEOLOGIST

Mr. GLENN. Thank you, Madam Chair. Thank you, Senator Inhofe and members of the Committee. Thank you for the opportunity to provide comments.

My name is Richard Glenn, and I am the board present of the Barrow Arctic Science Consortium. This is an organization dedicated to bringing visiting researchers together with Arctic residents. I am an officer of the Arctic Slope Regional Corporation, which is a corporation for the Native people of Alaska's North Slope. I am here today as an Alaskan resident who studies sea ice, as a subsistence hunter, a whaling crew co-captain and a geologist. This issue is very important to me.

I have only 5 minutes an my oral comments will summarize the most important points of my more detailed written testimony. I have studied sea ice for university-level work and have assisted many others in the sea ice environment. We Inupiaq hunters hunt on the ice each year, and our lives depend and the safety of our people depends on our knowledge of changing ice conditions.

Along with many of our people, I am concerned about changing sea ice conditions. However, I question whether the loss of multi-year sea ice equals the loss of polar bear habitat. The most prominent point made by the Fish and Wildlife Service is about receding multi-year sea ice cover and its equivalence to the loss of polar bear habitat. There is little mention of the marginal ice zone, that area of ice that freezes and melts within a given year, mixed with open water and older ice. It is in this area that it grows at the expense of the loss of multi-year ice.

The polar bear does not live only on the multi-year ice pack. Polar bears thrive in many settings. In late spring, polar bears come to the near-shore land-fast ice to hunt newborn seal pups located in dens beneath snow drifts. In summer, we observe polar bears hunting farther offshore in the marginal ice zone. Other polar bears will stay on the coast, not trapped there by the absence of sea ice, but to feed on living or dead animals along the shoreline. Groups of bears have even been seen by our villagers establishing an over-wintering circle around a carcass, such as dead gray whale.

My point is, none of the above hunting environments is on the multi-year ice pack. There is a year-long and varied cycle of habitats for polar bears. It is wrong to ignore them and focus only on how far the ice has receded. To do so is to ignore the polar bear's use of other habitats. Even the Fish and Wildlife Service study acknowledges that the increase of marginal ice cover may be beneficial for ice seals and polar bears.

The proposed listing is not based on polar bear population levels or trends. There is not enough observational data for a listing. Polar bears are hard to count, and ice conditions are not so easy to predict form models or satellites. The proposed rule correlates a decline of sea ice cover with a decline of ring seals. The data is insufficient to support even this conclusion. Right now, in the Chukchi Sea, the satellites will tell you that our ocean is covered with new, young ice, and not the multi-year ice pack. Nevertheless, our hunters are reporting abundant and healthy ring seals as well as polar bears.

There are many international mechanisms set up to conserve and protect the polar bear. In moving to the Endangered Species Act, let us not ignore those, such as the Marine Mammal Protection Act. If we really want to protect the species, let's do something about poaching, poaching by other countries. Alaskan Inupiaq people annually take about 45 to 50 bears from the Chukchi stock. Yet the same stock is suffering from poaching on the Russian side, with catch numbers around 200 per year.

Our traditional knowledge is built upon thousands of years of experience in the Arctic environment. I encourage Congress to use our experience and science before taking action to list the polar bear as threatened. This is common sense and required by law.

Senator BOXER. You have more time, if you want to go on.

Mr. GLENN. Oh, I heard a buzzer. I thought you were——

Senator BOXER. Not at all. You have another 45 seconds. Go right ahead.

Mr. GLENN. A threatened listing for the polar bear, Madam Chair, will do little to aid the polar bear's existence. It will not create more sea ice cover. It will not change their ability to locate dens or prey. But it will disproportionately affect the lives of Inupiaq Eskimos who live along the Arctic coast. While America sleeps better at night falsely believing they have assisted this iconic species, they will still fly planes, drive cars and power their homes. We are very concerned about changes in climate changes in the Arctic, and have more reason than others to be aggressive. The proper methods to address those issues are to deal with climate change causes directly and not twist the Endangered Species Act listing of the polar bear into action directed at climate change.

Thank you.

[The prepared statement of Mr. Glenn follows:]

Statement of Richard Glenn
To the Committee on Environment and Public Works
United States Senate
On
Examining Threats to and Protections of Polar Bear
January 30, 2008

Madam Chair, Senator Inhofe, and Members of the Committee, thank you for the opportunity to appear here today. I appreciate your effort to hear from Alaskan Arctic residents and Alaska's Inupiaq people on these most important issues.

Introduction

My name is Richard Glenn. I am here today as an Alaskan Arctic resident who studies sea ice, a subsistence hunter and whaling crew co-captain, and a geologist. I am also an incorporator and the board President of the Barrow Arctic Science Consortium, which is an organization that fosters the ongoing productive relationship between visiting researchers and local experts within our Native community. I am also a board member and officer of the Arctic Slope Regional Corporation (ASRC), the Alaska Native Regional Corporation for the Native people of Alaska's North Slope. While I wear many hats, I am appearing here today as an Inupiaq resident of Alaska's Arctic.

I have studied sea ice for years, studied it for University-level work and have assisted many others in the sea ice environment, including ice scientists, Navy dive teams, journalists and biologists. We Inupiaq hunters live and hunt on the ice each year, so our lives and safety depend on our knowledge of ever-changing ice conditions.

Ice Conditions and Relation to Polar Bear

I, along with many of our people, am concerned about the changing sea ice conditions that we have experienced in the last few years. We are watching it closely, on a day to day basis, as well as seasonally, to understand what is occurring in our ocean environment, and, most significantly for us, what those changes mean for the resources on which we depend for our way of life.

The most prominent point made by the Fish and Wildlife Service in its proposal to list the polar bear as a threatened species under the ESA is about receding perennial ice pack and its equivalence as a "loss of habitat". It also mentions increased fetches of open water, and its effects on denning and feeding. There is little mention of the marginal ice zone which must grow at the expense of a receding perennial pack. The marginal ice zone is comprised of ice that freezes and melts within a given year, and may contain fragments of older multiyear ice as well as areas of open water.

In addition to hunting at breathing holes and wind-driven lead edges in winter, polar bears thrive in many settings. In waters offshore of Barrow, for example we hunters see polar bears come closer to shore in late spring when the ringed seals give birth to pups beneath stable snowdrifts on landfast sea ice. The bears smell the odor of dens of newborn seal pups beneath snowdrifts.

In summer we observe polar bears hunting in the marginal ice zone. This coincides with the arrival of the walrus herds, and bears hunt them along with seals on and around drifting ice floes. I believe this is where polar bears thrive, because they can catch napping prey on ice floes, or use the floes for cover to catch animals in the water.

Some polar bears will also stay on the coast in the summer months, not trapped there by the absence of ice, but to feed on dead grey whales that have washed ashore, or on walrus and seals basking on the beach.

In autumn and winter some bears continue to feed on the remains of dead animals that have washed ashore. Groups of bears have been seen by our villagers establishing an over-wintering circle around a carcass, such as a grey whale. And yes, as the Fish and Wildlife Service notes, they also feed on the remains of bowhead whales harvested by fall-time whale hunters of the three eastern North Slope villages. Much has been written about the presence of bears around bowhead remains, but it is simply a part of their natural feeding cycle.

None of the above hunting environments is on the multi-year ice "pack". My point is there is a yearlong and varied cycle of habitat, ice environment, prey animals and food sources for polar bears in our region, including marginal ice zones, shorelines, inland areas, leads, and multi-year ice. As you consider receding ice, it is very important to also consider the other aspects of the polar bear's habitat---it is wrong to ignore these aspects and focus only on how far the ice has receded in recent summers. To do so, is to ignore polar bear behavior and use of other habitats.

The Fish and Wildlife Service acknowledges that the increase of marginal ice and corresponding reduction of multi-year ice cover may even be beneficial for ice seals and polar bears.

Polar Bear Populations

The proposed listing of the polar bear, is not based on polar bear population levels or trends, but based on the art of modeling. There is not on enough observational data as there should be for a listing. I am concerned that the listing is directed at being used as a legal tool to address climate change issues well away from the Arctic, not as a means to conserve a species.

Polar bears are hard to count. For example, the population of the polar bears of the Chukchi Sea region is estimated to be 2,000, based "on extrapolation of aerial den surveys", but these surveys are not sufficiently reliable to provide an accurate population count. Polar bear population researchers do not appear to take into account migrating animals within a population. Scientists have documented bear denning on the pack ice in the central Beaufort Sea and those dens, subsequently, drifting with the pack ice. As just one example, in the span of several months, a den had drifted from the central Beaufort Sea to the Wrangel Island vicinity, offshore of the Russian Far East. The mother and cub(s) emerged from the den there and made a beeline back to the Beaufort. What does this imply? That bears and dens can drift great distances, and that there may be flux between population stocks.

The accuracy of current population counts is a threshold issue in an ESA listing, and should be determined with a greater degree of certainty than that exhibited in the proposed rule.

The proposed rule correlates a decline of multi-year ice cover with a decline in the abundance and distribution of ringed seal, a primary prey of the polar bear. Yet the data used by USFWS is insufficient to support this key conclusion. For example, right now in the Chukchi Sea, the satellites will tell you that our ocean is covered with new, young ice and not the multi-year pack. Nevertheless, our hunters are finding abundant and healthy ringed-seals as well as polar bears.

Existing National and International Regulatory Mechanisms

There are many international mechanisms, laws and commissions set up to conserve and protect the polar bear. Some of these have been strengthened in recent years. In moving to the Endangered Species Act, let us not ignore those groups and activities and laws such as the Marine Mammal Protection Act. The actions that work best in the Arctic are the actions that respect and work with the Native people of the Arctic. Please do not skip over these means and measures to protect polar bear. These actions and forums, several of which have recently been strengthened, have not been thoroughly acknowledged by USFWS in its proposed listing. These actions and forums should be better understood in Congress, and not glossed in focusing on the Endangered Species Act. The ESA is only one means of protecting polar bears, not the only means.

Federal harvest data show that the take of polar bears by Inupiat people is sustainable. Inupiat Eskimos take about 45-50 bears from the Chukchi stock, for example. Yet the same stock is suffering from poaching on the Russian side, with catch numbers thought to be around 200 per year. If we really want to protect the species, let's do something about polar bear poaching by other countries.

Traditional Knowledge and Consultation

Our knowledge is both traditional and scientific as many Inupiaq people are involved in conducting and supporting scientific research on wildlife, sea ice conditions and climate change. Our traditional knowledge is built upon thousands of years of experience with the polar bear and its habitat. We monitor environmental changes closely because they are critical to our subsistence way of life and our culture. I encourage the federal government, and the Congress, to seek and use the breadth of knowledge and year-round, first hand traditional knowledge held by the Inupiaq people before taking action to list the polar bear as threatened under the ESA. This type of consultation with the most knowledgeable and affected Native people of the region is both common sense and required by law and federal policy.

ESA Listing of Polar Bear as a Means to Affect Climate Change Policies

I believe that a threatened listing for the polar bear will do little to aid the polar bears' existence. It will not create more sea ice cover. It will not change their ability to locate dens or prey. But it will negatively and disproportionately affect the lives of the people, the Inupiat Eskimos, who co-exist with the polar bear in the Alaskan Arctic. Our small, isolated communities will run the risk of becoming included in "Critical Habitat", even though we have no measurable impact on polar bear. What few playgrounds, gravel pits, airstrips, landfills, campsites, hunting areas, and village expansions that we have scattered along Alaska's northern arctic coast may be limited by the subjective process invoked by the Endangered Species Act. While America sleeps better at night, falsely believing they have assisted this iconic species, they will still fly planes, drive cars, and power their homes.

We are very concerned about changes in climate conditions in the Arctic and have more reason than others to be aggressive about addressing climate change; however, the proper methods to address those issues are to deal with climate change conditions and causes directly, not to twist the ESA listing of the polar bear into an action directed at climate change.

Conclusion

Madam Chair, the Arctic is a beautiful, and yes, changing environment. It has been the home of the Inupiat for thousands of years. We appreciate the effort that you and Senator Inhofe have made to hear the concerns from those of us that have the most experience with the Arctic's unique climate, which is home to our people and the polar bear.

Thank you for the opportunity to testify here today. I would be happy to answer any questions that you or the members of the Committee may have.

RESPONSE BY RICHARD GLENN TO AN ADDITIONAL QUESTION FROM SENATOR BOXER

Question. The Committee has received a statement for Ihere cord from groups representing Canadian Inuit peoples indicating that Ihe U.S. Fish and Wildlife Service has failed to sufficienlly consider Inuit Traditional Knowledge of Ihe polar bears during Ihe rulemaking process. They also state that USFWS does not consider or even examine the polar bear's abilily to adapt to changing and ice-free conditions. Do you agree that the USFWS is relying too much on computer models to determine the behavior, movement and overall health of polar bear populations? Could you provide some additional comment on this from the Alaska Inupiaq perspective?

Response. In large part, the Canadian and Alaskan Inuit are in agreement. As I spent time in our villages discussing this issue with residents, I was repeatedly asked, "Why doesn't Fish and Wildlife come to our villages and ask us?" Inupiat hunters, our experts in the ice and animal sciences, have not been consulted throughout this process-specifically the USFWS has not sought our input or expert observations.

The policymaking arm of the USFWS has little regard for input from the Native traditional knowledge. USFWS scientists have worked, over time, in places with local Native experts in very field-specific expeditions such as at Barter Island and Barrow. However, USFWS fail to incorporate traditional knowledge when they take their field research and attempt to synthesize it into publications that have far-reaching interpretations.

Further, USFWS substitutes polar bear researchers for ice experts when talking about the future of the Arctic Ocean ice environment.

Senator BOXER. Thank you, sir. Right on the nose.

Dr. Armstrong, we welcome you. You are a Professor of Marketing at the Wharton School. Welcome.

STATEMENT OF J. SCOTT ARMSTRONG, PH.D., PROFESSOR OF MARKETING, THE WHARTON SCHOOL, UNIVERSITY OF PENNSYLVANIA

Mr. ARMSTRONG. Thank you, Madam Chair, and thank the Committee for hearing me today.

My name is Scott Armstrong, I am a Professor at the Wharton School at the University of Pennsylvania.

As stated, the primary problem we are looking at today is what might happen to polar bears in the future. So I am addressing this Committee as an expert on forecasting. I have been working in the field for 48 years now.

Please direct your attention to Exhibit 1. It is also in the report at the end. It is an unlabeled exhibit. The dots represent data points. As you look at that, assume you had the forecast for the rest of the 21st century. Is it going up, down, staying the same, or what is happening? I will come back to that later in the talk.

In the mid–1990's, I started a project, the Principles of Forecasting Project. The idea was to summarize all of the knowledge that we had about forecasting and transform these into scientific principles. Here is an example. Be conservative in situations involving uncertainty. The project led to my handbook, "Principles of Forecasting," in which 39 authors and 123 reviewers participated.

Along with Dr. Kesten Green and Dr. Willie Soon, I examined two of the reports we have been talking about today. These are the reports by Amstrup and Hunter. We looked at those, because they are the ones most closely related to forecasting. We asked, "Did the authors' procedures follow scientific principles?" We made independent ratings, discussed them over followup rounds and reached agreement.

Here is an example: keep the forecast independent of organizational politics. We all rated that as a contravention of the principle. Why? Because if you look at the front page of all these reports, they say that the purpose of the report is to support the polar bear listing decision.

The reports involve a complex set of assumptions. In effect, they made assumptions where they should have made forecasts. The assumptions lacked validity, and we judged the reports to be invalid on that basis.

But we went further. We said, what if all those assumptions were true? Did they at least use the proper methods to arrive at a polar bear forecast?

I would like you to look at Exhibit 2. This shows the results of our audit. We found that the Amstrup report contravened 41 of the principles, the Hunter report contravened 61, and so on down the line. What is most important to look at is how many principles did they really follow? And it turns out that they properly applied, in the case of Amstrup, 17, and in the case of Hunter, 10.

Now, on a percentage basis, that means they followed 12 percent of the relevant principles. I wonder how many occupations there are in our Country where you can follow only 12 percent of the recommended policy and procedures?

The forecasts in those reports rested heavily on unaided judgment. By unaided, expert judgment, I mean unaided by scientific principles. Now, consider this. Unaided experts' forecasts are of no value when the situation is complex and uncertain. It is an astounding finding. I will repeat: unaided expert forecasts are of no value when the situation is complex and uncertain. I ran across this in my long-range forecasting book in 1978. Dr. Tetlock recently came out with a massive 20-year study supporting this. His study involved over 80,000 forecasts.

Please look again at the original unlabeled graph. I am now going to show you how the administrative report forecast that polar bear population would decrease rapidly. The graph relates to ice-free days and it comes from one of the Administration reports. They forecasted a sharp increase in ice-free days. How is that possible from the data? It is not possible. It only happened because they ignored the data. Instead, they relied on climate models.

The climate models do not provide forecasts. They provide so-called scenarios. Now, let's examine the graph with labels. The filled-in dots that you will see show the data that were used to determine the relationship between ice-free days and the polar bear population, 5 years. Now, is it possible to estimate this causal relationship with 5 years of observations? The answer is no.

The above analysis indicated contraventions of principles such as, use all available important data, use the most recent data, use simple forecasting methods and be conservative in cases of high uncertainty.

I would like to end on a very positive note. We know how to approach this problem in a scientific way.

Senator BOXER. OK, but you have to be positive in just a few seconds. But go ahead.

Mr. ARMSTRONG. I have six recommendations for approaching this in a scientific matter.

Senator BOXER. Just give one sentence for each one of them, and then you have gone over.

Mr. ARMSTRONG. Use a variety of forecasting methods; generate a list of alternative solutions and prepare forecasts; commission forecasts by independent teams; promote collaboration among polar bear climate experts along with forecasting experts; require forecasts be based on audited methods and don't tolerate any contraventions; combine all forecasts based on procedures that pass the audit.

Thank you, Madam Chairman.

[The prepared statement of Mr. Armstrong follows:]

Polar Bear Population Forecasts: A Public-Policy Forecasting Audit

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Abstract

The extinction of polar bears by the end of the 21st century has been predicted and calls have been made to list them as a threatened species under the U.S. Endangered Species Act. The decision on whether or not to list rests upon forecasts of what will happen to the bears over the 21st Century.

Scientific research on forecasting, conducted since the 1930s, has led to an extensive set of principles—evidence-based procedures—that describe which methods are appropriate under given conditions. The principles of forecasting have been published and are easily available. We assessed polar bear population forecasts in light of these scientific principles.

Nine government reports were prepared "...to Support U.S. Fish and Wildlife Service Polar Bear Listing Decision." None of the papers referred to works on scientific forecasting methodology. Of the nine papers, two appeared to be the most relevant to the listing decision: Amstrup, Marcot and Douglas (2007), which we refer to as AMD; and Hunter et al. (2007), which we refer to as H6 to represent the six authors.

AMD's and H6's forecasts were each products of complex sets of assumptions. Both incorrectly assumed first that General Circulation Models (GCMs) are valid tools for forecasting summer sea ice in the regions inhabited by polar bears. In fact, GCMs did not even provide reliable good fits of summer sea ice when estimated and run over historical periods. A primary assumption of both AMD and H6 therefore lacks support. We nevertheless audited their conditional forecasts of what would happen to the polar bear population *assuming* as they did that the extent of summer sea ice will decrease substantially in the coming decades.

AMD could not be rated against 26 relevant forecasting principles because the paper did not contain enough information. In all, AMD contravened 73 of the 90 forecasting principles we were able to rate. In fact, they properly applied only 15% of the relevant principles. They used two un-validated methods and relied on only one polar bear expert to specify variables, relationships, and inputs into their models. The same expert then adjusted the models until the outputs conformed to his expectations. In effect, the forecasts were the opinions of a single expert unaided by forecasting principles. Based on research to-date, approaches based on unaided expert opinion are inappropriate for forecasting in situations with high complexity and much uncertainty.

Our audit of the second paper, H6, found that like AMD, the authors' forecasting procedures contravened many forecasting principles. For example, they relied heavily on five years of data to forecast polar bear populations over the remainder of the 21st Century. They properly applied only 10% of the relevant principles.

In summary, experts' forecasts that are unaided by evidence-based forecasting procedures, should not be used for forecasting in this situation. The decision of whether to list polar bears should be based on scientific forecasts of their population *and* forecasts of net benefits from feasible policies arising from listing polar bears. We recommend the use of the forecasting audits to ensure that the forecasts are properly done.

Key words: adaptation, bias, climate change, decision making, endangered species, expert opinion, evaluation, evidence-based principles, expert judgment, extinction, forecasting methods, global warming, habitat loss, matbematical models, scientific method, sea ice.

Introduction

Polar bears have been described by some as the "canaries of climate change," and concerns have been expressed over the survival of some sub-populations. We assessed the validity of long-term forecasts of selected polar bear populations by asking "Are the forecasts derived from accepted scientific procedures?"

We first examined the references in the nine unpublished government reports written to support listing polar bears under the Endangered Species Act. Second, we examined the forecasting methods employed in two of those nine reports by assessing the procedures described in the reports against forecasting principles. We use the term "forecasting principles" to refer to guidelines on the selection of forecasting methods. The principles are based on evidence from scientific research that has revealed which methods provide the most accurate forecasts for a given situation.

Scientific forecasting procedures

Scientific research on forecasting has been conducted since the 1930s; important findings from the extensive literature on forecasting were first summarized in Armstrong (1978, 1985).

In the mid-1990s, the Forecasting Principles Project was established with the objective of summarizing all useful knowledge about forecasting. The evidence was codified as principles, or condition-action statements, to provide guidance on which methods to use under different circumstances. The project led to the *Principles of Forecasting* handbook (Armstrong 2001). These principles were formulated by 40 internationally-recognized experts on forecasting methods and were reviewed by 123 leading experts on forecasting methods. The summarizing process alone was a four-year effort. We refer to the evidence-based methods as scientific forecasting procedures.

The strongest form of evidence is that which is derived from empirical studies that compare the performance of alternative methods. Ideally, "performance" is assessed by the ability of the selected method to provide useful *ex ante* forecasts. The weakest form of evidence is based on received wisdom about proper procedures. However, some of these principles seem self-evident (e.g., "Provide complete, simple and clear explanations of methods") and, as long as they were unchallenged by the available evidence, they were included. Some important principles are counter-intuitive: as a consequence, forecasts derived in ignorance of forecasting principles have no scientific standing.

The forecasting principles are available on forecastingprinciples.com, a site sponsored by the International Institute of Forecasters. The site claims to provide "all useful knowledge about forecasting" and asks visitors to submit any missing evidence. The Forecasting Principles site has been at the top of the list of sites in Internet searches for "forecasting" for many years.

A summary of the principles, currently numbering 140, is provided as a checklist in the Forecasting Audit software available on the site. The strength of evidence is summarized briefly for each principle, and details are provided in Armstrong (2001) as well as in papers posted on the site.

General Assessment of Long-Term Polar Bear Population Forecasts

We examined the references cited in the nine unpublished USGS Administrative Reports posted on the Internet at http://usgs.gov/newsroom/special/polar_bears/. They were: Amstrup et al. (2007); Bergen et al (2007); DeWeaver (2007); Durner et al. (2007); Hunter et al. (2007); Obbard et al. (2007); Regehr et al. (2007); Rode et al. (2007); and Stirling et al. (2007). The USGS Administrative Reports included 444 unique references in total. We were unable to find any references that related to the validation of forecasting methods.

Forecasting Audit of Two Key Papers Prepared to Support an Endangered Listing

We audited the forecasting procedures used in what we judged to be the two most crucial of the nine papers commissioned by the U. S. Department of the Interior to support the petition to classify polar bears as an endangered species.

The evidence-based principles upon which our audit was based were derived from many areas, including management, psychology, economics, politics, and weather, with the intention that they would apply to any type of forecasting problem. Some reviewers of our research have suggested that the principles do not apply to the physical sciences. We have asked reviewers for evidence to support that viewpoint, but have been unable to obtain useful responses. Readers can examine the principles and form their own judgments on this issue. For example, might one argue that the principle, "Ensure that information is reliable and that measurement error is low," does not apply when forecasting climate?

In conducting the audits, each of the three authors read the paper and independently rated the forecasting procedures described in it by using the Forecasting Audit software at forecastingprinciples.com. The rating scale runs from –2 to +2, with the former indicating the procedures contravene the principle and the latter signifying that it is properly observed. After the initial round of ratings, we examined differences in our ratings in an attempt to reach consensus. To the extent that we had difficulty in reaching consensus, we moved ratings toward "0".

Clearly forecasting audit ratings involve some subjectivity. Despite this, for each of the papers our ratings after the first round were in substantial agreement. Furthermore, we had little difficulty in reaching consensus by the third round.

In some cases, the two papers did not provide sufficient details to allow for ratings. To resolve this issue, we contacted the authors of the two papers and requested further information. In addition, we asked them to review our ratings and to tell us whether they disagreed with any of them. In their reply, they refused to provide any responses to our requests. (See Note 2 at the end of our paper.)

At various points in our audit report, we cite studies that provide relevant evidence. To ensure that we cited them properly, we sent a copy of our paper to all authors that we cited in a substantive manner in December 2007 asking them to inform us if we had not properly referred to their findings. None of the authors objected to the way that we summarized their research. We also invited them to review the paper.

Audit of AMD

We audited Amstrup, Marcot, and Douglas (2007), which we will refer to as AMD. That paper made forecasts of polar bear populations for 45, 75, and 100 years from the year 2000.

AMD implicitly made many assumptions: (1) global warming will occur; (2) this will both reduce the extent of and thin the summer sea ice; (3) polar bears will obtain less food by hunting from the sea ice platform than they do now; (4) they will not obtain adequate supplementary food using other means or from other sources; (5) the bear population will decline; (6) the designation of polar bears as an endangered species will solve the problem and will not have serious detrimental effects; and (7) there are no other policies that would produce better outcomes than those based on an endangered species classification.

AMD assumed that the general circulation models (GCMs) provide scientifically valid forecasts of global temperature and the extent and thickness of sea ice. They stated (AMD 2007, p. 2 and Fig 2 p. 83): "Our future forecasts are based largely on information derived from general circulation model (GCM) projections of the extent and spatiotemporal distribution of sea ice." That is, their forecasts are conditional on long-term global warming forecasts leading to a dramatic reduction in Arctic sea ice during maximum melt-back periods in spring, late summer and fall.

Green and Armstrong (2007) examined long-term climate forecasting efforts and were unable to find a single forecast of global warming that was based on scientific methods. The climate modelers' procedures did not follow many forecasting principles and some of the contraventions were critical. This formal auditing result is consistent with earlier cautions. For example, Soon et al. (2001) found that the current generation of GCMs is unable to meaningfully calculate the climatic effects of added atmospheric carbon dioxide given the severe limitations from both the uncertainties and unknowns in representing all relevant physical processes.

The fact that the AMD forecasts rest on the GCM forecasts and that these forecasts lack a scientific basis puts their assumptions into question. Indeed, some climate modelers state that the GCMs do not provide forecasts. Furthermore, the GCM models have not been designed for analysis at a regional level in the way they are used by AMD and H6 (see the discussion of Principle 9.2 in H6 below).

We audited AMD's polar bear population forecasting procedures to assess whether they would produce valid forecasts assuming valid climate and sea ice forecasts were available as inputs. Of the 140 forecasting principles, we agreed that 24 were irrelevant to the forecasting problem. We then examined principles on which our ratings differed. After two rounds of consultation (i.e., the process required three rounds in all), we were able to reach consensus on all 116 relevant principles. We found that AMD's procedures contravened 41 principles (Table 1) and apparently contravened 32 principles (Table 2). We were unable to rate 26 relevant principles (Table 3) due to a lack of information.

Table 1: Principles contravened in AMD

Setting Objectives:

1.2 Prior to forecasting, agree on actions to take assuming different possible forecasts.
1.3 Make sure forecasts are independent of politics.
1.4 Consider whether the events or series can be forecasted.
1.5 Obtain decision makers' agreement on methods.

Identify Data Sources:

3.5 Obtain information from similar (analogous) series or cases. Such information may help to estimate trends.

Collecting Data:

4.2 Ensure that information is reliable and that measurement error is low.

Selecting Methods:

6.1 List all the important selection criteria before evaluating methods.
6.2 Ask unbiased experts to rate potential methods.
6.7 Match the forecasting method(s) to the situation
6.8 Compare track records of various forecasting methods.
6.10 Examine the value of alternative forecasting methods.

Implementing Methods: General

7.3 Be conservative in situations of high uncertainty or instability.

Implementing Judgmental Methods:

8.1 Pretest the questions you intend to use to elicit judgmental forecasts.
8.2 Frame questions in alternative ways.
8.5 Obtain forecasts from heterogeneous experts.
8.7 Obtain forecasts from enough respondents.
8.8 Obtain multiple forecasts of an event from each expert.

Implementing Quantitative Methods:

9.1 Tailor the forecasting model to the horizon.
9.3 Do not use "fit" to develop the model.
9.5 Update models frequently.

Implementing Methods: Quantitative Models with Explanatory Variables:

10.6 Prepare forecasts for at least two alternative environments.
10.8 Apply the same principles to forecasts of explanatory variables.
10.9 Shrink the forecasts of change if there is high uncertainty for predictions of the explanatory variables.

Combining Forecasts:

12.1 Combine forecasts from approaches that differ.
12.2 Use many approaches (or forecasters), preferably at least five.
12.3 Use formal procedures to combine forecasts.
12.4 Start with equal weights.

Evaluating Methods:

13.6 Describe potential biases of forecasters.
13.10 Test assumptions for validity.
13.32 Conduct explicit cost-benefit analyses.

Assessing Uncertainty:

14.1 Estimate prediction intervals (PIs).
14.2 Use objective procedures to estimate explicit prediction intervals.
14.3 Develop prediction intervals by using empirical estimates based on realistic representations of forecasting situations.
14.5 Ensure consistency over the forecast horizon.
14.7 When assessing PIs, list possible outcomes and assess their likelihoods.
14.8 Obtain good feedback about forecast accuracy and the reasons why errors occurred.
14.9 Combine prediction intervals from alternative forecasting methods.
14.10 Use safety factors to adjust for overconfidence in the PIs.
14.11 Conduct experiments to evaluate forecasts.
14.13 Incorporate the uncertainty associated with the prediction of the explanatory variables in the prediction intervals.
14.14 Ask for a judgmental likelihood that a forecast will fall within a pre-defined minimum-maximum interval

Table 2: Principles apparently contravened in AMD

Structuring the problem:

2.1 Identify possible outcomes prior to making forecasts.
2.7 Decompose time series by level and trend.

Identify Data Sources:

3.2 Ensure that the data match the forecasting situation.
3.3 Avoid biased data sources.
3.4 Use diverse sources of data.

Collecting Data:

4.1 Use unbiased and systematic procedures to collect data.
4.3 Ensure that the information is valid.

Selecting Methods:

6.4 Use quantitative methods rather than qualitative methods.
6.9 Assess acceptability and understandability of methods to users.

Implementing Methods: General

7.1 Keep forecasting methods simple.

Implementing Quantitative methods:

9.2 Match the model to the underlying phenomena.
9.4 Weight the most relevant data more heavily.

Implementing Methods: Quantitative Models with Explanatory Variables:

10.1 Rely on theory and domain expertise to select causal (or explanatory) variables.
10.2 Use all important variables.
10.5 Use different types of data to measure a relationship.

Combining Forecasts:

12.5 Use trimmed means, medians, or modes
12.7 Use domain knowledge to vary weights on component forecasts.
12.8 Combine forecasts when there is uncertainty about which method is best.
12.9 Combine forecasts when you are uncertain about the situation.
12.10 Combine forecasts when it is important to avoid large errors.

Evaluating Methods:

13.1 Compare reasonable methods.
13.2 Use objective tests of assumptions.
13.7 Assess the reliability and validity of the data.
13.8 Provide easy access to the data.
13.17 Examine all important criteria.
13.18 Specify criteria for evaluating methods prior to analyzing data.
13.27 Use ex post error measures to evaluate the effects of policy variables.

Assessing Uncertainty:

14.6 Describe reasons why the forecasts might be wrong.

Presenting Forecasts:

15.1 Present forecasts and supporting data in a simple and understandable form.
15.4 Present prediction intervals.

Learning That Will Improve Forecasting Procedures:

16.2 Seek feedback about forecasts.
16.3 Establish a formal review process for forecasting methods.

Table 3: Principles not rated due to lack of information in AMD

Structuring the problem:

2.5 Structure problems to deal with important interactions among causal variables.

Collecting data:

4.4 Obtain all of the important data
4.5 Avoid the collection of irrelevant data

Preparing Data:

5.1 Clean the data.
5.2 Use transformations as required by expectations.
5.3 Adjust intermittent series.
5.4 Adjust for unsystematic past events.
5.5 Adjust for systematic events.
5.6 Use multiplicative seasonal factors for trended series when you can obtain good estimates for seasonal factors.
5.7 Damp seasonal factors for uncertainty

Selecting Methods:

6.6 Select simple methods unless empirical evidence calls for a more complex approach.

Implementing Methods: General

7.2 The forecasting method should provide a realistic representation of the situation

Implementing Judgmental Methods:

8.4 Provide numerical scales with several categories for experts' answers.

Implementing Methods: Quantitative Models with Explanatory Variables:

10.3 Rely on theory and domain expertise when specifying directions of relationships.
10.4 Use theory and domain expertise to estimate or limit the magnitude of relationships.

Integrating Judgmental and Quantitative Methods:

11.1 Use structured procedures to integrate judgmental and quantitative methods.
11.2 Use structured judgment as inputs to quantitative models.
11.3 Use pre-specified domain knowledge in selecting, weighting, and modifying quantitative methods.
11.4 Limit subjective adjustments of quantitative forecasts.

Evaluating Methods:

13.4 Describe conditions associated with the forecasting problem.
13.5 Tailor the analysis to the decision.
13.9 Provide full disclosure of methods.
13.11 Test the client's understanding of the methods.
13.19 Assess face validity.

Assessing Uncertainty:

14.12 Do not assess uncertainty in a traditional (unstructured) group meeting.

Learning That Will Improve Forecasting Procedures:

16.4 Establish a formal review process to ensure that forecasts are used properly.

We describe some of the more serious problems with the AMD forecasts below:

Match the forecasting method(s) to the situation (Principle 6.7)

The forecasts in AMD rely on the opinions of an expert who is knowledgeable in the domain. The opinions were transformed into a complex set of formulae, but were unaided by evidence-based forecasting principles.

Some studies (e.g., Tetlock 2005) suggest that judgmental forecasts by researchers who ignore accepted forecasting principles have little value in complex and uncertain situations. This apparently applies whether the opinions are expressed in words, spreadsheets, or mathematical models. It also applies regardless of how much scientific information is used by the experts. Among the reasons for this are:

a) Complexity:	Individuals cannot assess complex relationships through unaided observations.
b) Coincidence:	Individuals confuse correlation with causation.
c) Feedback:	Individuals making judgmental predictions typically do not receive unambiguous feedback they can use to improve their forecasting.
d) Bias:	Individuals have difficulty in obtaining or using evidence that contradicts their initial beliefs. This problem is especially serious among individuals who view themselves as experts.

Despite the lack of validity of unaided forecasts by experts, many public policy decisions are based on such forecasts. Research on persuasion has shown that people have substantial faith in the value of such forecasts and that faith increases when experts agree with one another. Although they may seem convincing at the time, expert forecasts can, a few years later, serve as important cautionary tales. Cerf and Navasky's (1998) book contains 310 pages of examples, such as Fermi Award-winning scientist John von Neumann's 1956 prediction that "A few decades hence, energy may be free". Examples of expert climate forecasts that turned out to be wrong are easy to find, such as UC Davis ecologist Kenneth Watt's prediction in a speech at Swarthmore College on Earth Day, April 22, 1970 that "If present trends continue, the world will be about four degrees colder in 1990, but eleven degrees colder in the year 2000. This is about twice what it would take to put us into an ice age."

Are such examples merely a matter of selective perception? The first author's review of empirical research on this problem led him to develop the "Seer-sucker Theory," which can be stated as "No matter how much evidence exists that seers do not exist, seers will find suckers" (Armstrong 1980). The amount of expertise does not matter beyond a basic minimum level. There are exceptions to the Seer-sucker Theory: experts can improve their forecasting when they receive well-summarized feedback on the accuracy of their forecasts and reasons why their forecasts were or were not accurate. This situation applies for short-term (up to five day) weather forecasts, but we are not aware of any such regime for long-term global climate forecasting. Even if there were such a regime, the feedback would trickle in over many years before it became useful for improving forecasting. Moreover, experts typically resist negative feedback and prefer to provide excuses for inaccurate forecasts (Tetlock 2005).

Research since 1980 has added support to the Seer-sucker Theory. In particular, Tetlock (2005) recruited 284 people whose professions included "commenting or offering advice on political and economic trends." He asked them to forecast the probability that various situations would or would not occur, picking areas (geographic and substantive) within and outside their areas of expertise. By 2003, he had accumulated over 82,000 forecasts. The experts barely if at all outperformed non-experts and neither group did well against simple rules.

Many comparative empirical studies have concluded that judgmental forecasting by experts is the least accurate of the methods available to make forecasts. For example, Ascher (1978, p. 200), in his analysis of long-term forecasts of electricity consumption, found that that was the case.

AMD also implicitly forecast—that is, they used their judgment unaided by scientific forecasting procedures—that a policy to classify polar bears as a threatened species would save the bears from future possible extinction. AMD did not include forecasts of the costs, planned and unintended, of such a policy.

Be conservative in situations of high uncertainty or instability (Principle 7.3)

Forecasts should be conservative when a situation is unstable, complex or uncertain. Being conservative means moving forecasts towards "no change" or, in cases that exhibit a well established long-term trend and where there is no reason to expect the trend to change, being conservative means moving forecasts toward the trend line. A long-term trend is one that has been evident over a period that is *much longer* than the period being forecast. Conservatism is a fundamental principle in forecasting.

The interaction between polar bears and their environment in the Arctic is complex and there is much uncertainty. For example, AMD associated warm temperatures with lower polar bear survival rates, yet cold temperatures have also been associated with similar outcomes, as this quote illustrates: "Abnormally heavy ice covered much of the eastern Beaufort Sea during the winter of 1973-1974. This resulted in major declines in numbers and productivity of polar bears and ringed seals in 1975" (Amstrup et al. 1986, p. 249). Stirling (2002, p. 68 and 72) further expanded on the complexity of polar bear-sea-ice interactions:

> "In the eastern Beaufort Sea, in years during and following heavy ice conditions in spring, we found a marked reduction in production of ringed seal pups and consequently in the natality of polar bears ... The effect appeared to last for about three years, after which productivity of both seals and bears increased again. These clear and major reductions in productivity of ringed seals in relation to ice conditions occurred at decadal-scale intervals in the mid-1970s and 1980s ... and, on the basis of less complete data, probably in the mid-1960s as well ... Recent analyses of ice anomalies in the Beaufort Sea have now also confirmed the existence of an approximately 10-year cycle in the region ... that is roughly in phase with a similar decadal-scale oscillation in the runoff from the Mackenzie River ... However, or whether, these regional-scale changes in ecological conditions have affected the reproduction and survival of young ringed seals and polar bears through the 1990s is not clear."

Regional variability adds to uncertainty. For example, Antarctic ice mass extent has been growing while sea and air temperatures have been increasing (e.g. Zhang 2007). At the same time, depth-averaged oceanic temperatures around the Southeastern Bering Sea (Richter-Menge et al. 2007) have been cooling in 2006. Despite the warming of local air temperature by 1.6±0.6°C, there was no sharp decline in the area over the continental shelf of the Canadian Beaufort Sea that was ice-covered for the 36 years from 1968 to 2003 (Melling et al. 2005).

Despite the uncertainty, instability, and complexity of the situation, AMD made predictions based on assumptions that we view as questionable. They also used little historical data.

Obtain forecasts from heterogeneous experts (Principle 8.5)

AMD's polar bear population forecasts were the product of a single expert. Experts vary in their knowledge and the way they approach problems, and bringing more information and different approaches to bear on a forecasting problem improves accuracy. When sufficient information is not available, forecasting can not be assumed valid. Also, in situations where experts might be biased, it is important to obtain forecasts from experts with different biases. Failing to follow this principle increases the risk that the forecasts obtained will be extreme when, in this situation, forecasts should be conservative (see Principle 7.3, above).

Use all important variables (Principle 10.2)

Dyck et al. (2007) recently noted that scenarios of polar bear decline grossly oversimplify the complex ecological relationships of the situation. In particular, AMD did not adequately consider the adaptability of polar bears. They mentioned the fact that polar bears evolved from brown bears 250,000 years ago (p. 2) but they appear to have ignored the fact that polar bears probably experienced much warmer conditions in the Arctic over that extended time period, with periods when sea ice habitat was less than those expected over the next century according to the GCM projections AMD have used. Several studies (Hamilton and Brigham-Grette 1991; Brigham-Grette and Hopkins 1995; Norgaard-Pedersen et al. 2007) have documented the dramatic reduction of sea ice in both the Northwest Alaskan coast and Northwest Greenland part of the Arctic Ocean during the very warm Interglacial of marine isotope stage 5e *ca.* 130,000 to 120,000 years ago. Brigham-Grette and Hopkins (1995, p. 159) noted that the "winter sea-ice limit was north of Bering Strait, at least 800 km north of its present position, and the Bering Sea was perennially ice-free" and that "[the more saline] Atlantic water may have been present on the shallow Beaufort Shelf, suggesting that the Arctic Ocean was not stratified and the Arctic sea-ice cover was not perennial for some period." On the face of it, the nature and extent of polar bear adaptability seem crucial to any forecasts that assume dramatic changes in the bears' environment.

AMD's forecasts were commissioned to inform public policy decisions, but they do not explicitly forecast the effects of different policies. For example, in the event of the polar bear population coming under stress due to inadequate summer food, what would be the costs and effects of protecting areas by prohibiting marine and land-based activities at critical times? In addition, what would be the costs and benefits of a smaller but stable population of polar bears in some polar sub-regions? And how would the net costs of such alternative policies compare with the net costs of listing polar bears?

Make sure forecasts are independent of politics (Principle 1.3)

By politics, we mean any type of organizational biases or pressures. While different stakeholders may prefer particular forecasts, if forecasters are influenced by such considerations, forecast accuracy will suffer. The Executive Summary document[1] noted that "the Secretary of the Interior asked the U.S. Geological Survey (USGS) to generate new scientific data, models, and interpretations on polar bears and their sea ice habitats, to support the "U.S. Fish and Wildlife service polar bear listing decision" (http://www.doi.gov/news/06_News_Releases/061227.html). The authors of the AMD administrative report are all employees of the U.S. government agencies that are trying to support this decision.

Audit of Hunter et al (H6)

Hunter et al. (2007), which we refer to here as H6, forecasted polar bear numbers in the southern Beaufort Sea for 45, 75, and 100 years from 2000. To do so, they implicitly assumed the following: (1) global warming will occur; (2) frequent "bad years" will be a consequence of global warming; (3) polar bears will not adapt to "bad years"; (4) the population of polar bears will decline dramatically from negative effects of "bad years" alone; (5) the designation of polar bears as an endangered species will solve the problem and will not have serious detrimental effects; and (6) there are no other policies that would produce better outcomes than those based on listing polar bears under the Endangered Species Act.

Like AMD, H6 accepted GCM forecasts of global warming and reduced extent and thickness of sea ice. They stated that "we extracted forecasts of the availability of sea ice for polar bears in the SB [southern Beaufort Sea] region, using monthly forecasts of sea ice concentrations from 10 IPCC Fourth Assessment Report (AR4) fully-coupled general circulation models" (p. 11 of H6). That is, their forecasts are conditional on long-term forecasts of global warming producing dramatic effects. However, Green and Armstrong (2007) were unable to find any forecasts made

[1] http://www.usgs.gov/newsroom/special/polar_bears/docs/executive_summary.pdf

in accordance with scientific forecasting principles that support the hypothesized predictions of global warming throughout the 21st Century.

We nevertheless audited H6's polar bear population forecasting procedures to assess whether they would produce valid forecasts if valid climate and sea ice forecasts were available as inputs.

Each of the authors read H6 and independently rated the forecasting procedures described in it using the Forecasting Audit software at forecastingprinciples.com. Of the 140 forecasting principles, we agreed that 35 were irrelevant to the forecasting problem. We then examined principles on which our ratings differed, and after three rounds of consultation we were able to reach consensus on all 105 relevant principles. To the extent that we had difficulty in reaching consensus, we moved ratings toward "0".

We found that H6's procedures could clearly be improved for 61 principles (Appendix Table A) and probably be improved for an additional 19 principles (Appendix Table B). We were unable to rate 15 relevant principles (Appendix Table C) due to a lack of information.

Many of the contraventions in H6 were similar to those in AMD and we provide the H6 audit details in the appendix. Here are some examples of contraventions, some of which are, on their own, raise serious questions about the value of the H6 forecasts:

Decisions, actions, and biases (Principles 1.1 – 1.3)

The H6 authors did not describe alternative decisions that might be taken (1.1), nor did they propose relationships between possible forecasts and alternative decisions (1.2). For example, what decision would be implied by a forecast that bear numbers will increase to the point where they become a threat to existing human settlements? These problems relate to the biased manner in which the problem was stated: "USGS science strategy to support U.S. Fish and Wildlife Service polar bear listing decision" (1.3). Research is often prone to bias, sometimes due to unknown preferences or interests, but it is nevertheless important to try to avoid it, and it is clearly improper to undertake a research project on the understanding that there is a desired finding.

Ensure that information is reliable and that measurement error is low (Principle 4.2)

Long-term forecasts require enormous amounts of valid and reliable data. Armstrong (1985, p. 166) refers to two rules of thumb for how much data are needed for extrapolating *h* years ahead. One calls for $4h^{1/2}$ years of historical data and the other calls for *h* years. These rules imply that H6 should have based any extrapolations on 40 to 100 years of historical data.

H6 relies heavily on five years of data with unknown measurement errors. Furthermore, did the capture data on which they rely provide representative samples of bears in the southern Beaufort Sea given the vast area involved and difficulties in spotting and capturing the bears? Bears wander over long distances and do not respect administrative boundaries (Amstrup et al. 2004). The validity of the data is likely to be compromised further by imposing a speculative demographic model on the raw capture-recapture data (Amstrup et al. 2001; Regehr et al. 2006).

Be conservative in situations of high uncertainty or instability (Principle 7.3)

The situation regarding polar bears in the southern Beaufort Sea is complex and there is much uncertainty. For example, on the basis of five years of data, H6 associated warm temperatures with lower polar bear survival rates, yet as noted earlier, cold temperatures have also been associated with similar outcomes: "Abnormally heavy ice covered much of the eastern Beaufort Sea during the winter of 1973-1974. This resulted in major declines in numbers and productivity of polar bears and ringed seals in 1975" (Amstrup et al. 1986, p. 249).

As noted above, regional changes add to uncertainty, noting the Antarctic ice extent has been growing at the same time that sea and air temperatures have been increasing (e.g. Zhang 2007) while depth averaged oceanic temperatures around the southeastern Bering Sea have been undergoing relative cooling in 2006 (Richter-Menge et al. 2007). Despite the warming of local air temperature by 1.6±0.6°C, there was no sharp decline in the area over the continental shelf of the Canadian Beaufort Sea that was covered in ice for the 36 years from 1968 to 2003 (Melling et al. 2005).

Given all of the uncertainties, the H6 forecasts did not strike us as being conservative.

Tailor the forecasting model to the horizon (Principle 9.1)

When forecasting over the long term, as in H6, forecasting models should be based on long-term trends. However, the H6 authors built models based entirely on estimates derived from only five years of recent data.

Update frequently (Principle 9.5)

H6 did not include the most recent year, 2006, when estimating their model. From the supplementary information provided in Figure 3 of Regehr et al. (2007), one finds that the number of ice-free days for the 2006 season was about 105: close to the mean of the "good" ice years.

The latest "Alaska Marine Mammal Stock Assessment, 2006" report by Angliss and Outlaw (2007, p. 218), states that

> "The Southern Beaufort Sea [polar bear] Stock is not classified as 'depleted' under the MMPA or listed as 'threatened' or 'endangered' under terms of the Endangered Species Act. This stock is assumed to be within optimum sustainable population levels."

Use all important variables (Principle 10.2)

With causal models, it is important to incorporate policy variables if they might vary or if the purpose is to decide what policy to implement. H6 did not include policy variables such as seasonal protection of bears' critical habitat, or changes to hunting rules.

Other variables should also be included, such as migration, snow, and wind conditions. For example Holloway and Sou (2002), Ogi and Wallace (2007), and Nghiem et al. (2007) suggested that large-scale atmospheric winds and related patterns play an important role in causing – in some situations with significant time delays – both the decline in extent and thinning of Arctic sea ice; those effects were not correctly included in the GCM forecasts of sea ice (and hence the quality of polar bear habitat).

In addition, Dyck et al. (2007) recently noted that future scenarios of polar bear decline oversimplify the complex ecological relationships of the situation. This is why the extent and kind of polar bear adaptability is crucial to any forecasts that assume dramatic changes in the bears' environment.

Use different types of data to measure a relationship (Principle 10.5)

This principle is important when there is uncertainty about the relationships between causal variables (such as ice extent) and the event being forecast (polar bear population) and when large changes are expected in the causal variables. In the case of the latter condition, H6 accepted the GCM model predictions of large declines in summer ice throughout the 21st century, so their forecasts were sensitive to their estimate the quantitative effect of ice extent on polar bear populations. Yet H6 base their estimate of this important relationship on only five years of data with a limited range of climatic-ecological responses sampled. They might, for example, have independently estimated the magnitude of the relationship by obtaining estimates of polar bear populations during much warmer and much colder periods in the past. The supplementary information from Figure 3 of Regehr et al. (2007) shows that 1987, 1993 and 1998 were exceptional seasons with the number of ice-free days longer than 150 days (i.e., substantially above the 135 ice-free days documented for 2004-2005) in the southern Beaufort sea, yet there were no apparent negative impacts on the polar bear population and wellbeing – see for example, Amstrup et al. 2001).

Match the model to the underlying phenomena (Principle 9.2)

It is important for the readers to know what is meant by "Southern Beaufort Sea" (SB) in the H6 report because of the poor spatial resolution of the GCMs. H6 states: "Because GCMs do not provide suitable forecasts for areas as small as the SB, we used sea ice concentration for a larger area composed of 5 IUCN polar bear management units (Aars et al. 2006) with ice dynamics similar to the SB management unit (Barents Sea, Beaufort Sea, Chukchi Sea, Kara Sea and Laptev Sea; see Rigor and Wallace 2004, Durner et al. 2007). We assumed that the general trend in sea ice availability in these 5 units was representative of the general trend in the Southern Beaufort region." (p. 12). Given the unique ecological, geographical, meteorological, and climatological conditions in each of the five circumpolar seas, we did not find this assumption to be convincing.

When assessing prediction intervals (PIs), list possible outcomes and assess their likelihoods (Principle 14.7)

To assess meaningful PIs, it helps to think of diverse possible outcomes. The H6 authors did not appear to consider, for example, the possibility that polar bears might adapt to terrestrial life over summer months by finding alternative food sources (such as is the case in the Southern Hudson Bay populations, or elsewhere; see references in Stempniewicz 2006; Dyck and Romberg 2007) or by successfully congregating in smaller or localized ice-hunting areas. Consideration of these and other possible adaptations and outcomes would have likely led the H6 authors to be less confident (provide wider prediction intervals) about a bad outcome for bears. Extending this exercise to the forecasts of climate and summer ice extent would have further widened the range of other outcomes.

Summary and conclusions

We examined the nine administrative reports that were commissioned by the USGS with the stated purpose of supporting the listing of polar bears under the Endangered Species Act. Since the current population of bears is not at a level that causes concern, the case for listing depends upon forecasts of serious declines in bear numbers in decades to come.

We found that the two reports most relevant to the listing decision made some questionable assumptions. Even if these assumptions had been valid, the bear population forecasting procedures contravened many important forecasting principles. Table 4 summarizes our audits:

Table 4: Summary ratings from the forecasting audits

Principles	AMD	H6
Contravened	41	61
Apparently contravened	32	19
Not auditable	26	15
Properly applied	17	10

To provide credible scientific forecasts, forecasting procedures should properly apply all evidence-based principles. In other words, there should be no contraventions.

Decision makers and the public should expect to see scientific forecasts of both the polar bear population *and* the net benefits from feasible policies before any decision is made on whether to list polar bears as threatened or endangered. We recommend that important forecasting efforts such as this should observe all relevant principles and that their procedures be audited to ensure that they do so.

Appendix

Table A: Principles contravened in H6

Setting Objectives:

1.3 Make sure forecasts are independent of politics.
1.4 Consider whether the events or series can be forecasted.

Structuring the problem:

2.6 Structure problems that involve causal chains.

Identify Data Sources:

3.4 Use diverse sources of data.
3.5 Obtain information from similar (analogous) series or cases. Such information may help to estimate trends.

Collecting Data:

4.4 Obtain all of the important data

Preparing Data:

5.2 Use transformations as required by expectations.
5.4 Adjust for unsystematic past events.
5.5 Adjust for systematic events.

Selecting Methods:

6.1 List all the important selection criteria before evaluating methods.
6.2 Ask unbiased experts to rate potential methods.
6.6 Select simple methods unless empirical evidence calls for a more complex approach.
6.7 Match the forecasting method(s) to the situation.
6.8 Compare track records of various forecasting methods.
6.10 Examine the value of alternative forecasting methods.

Implementing Methods: General

7.1 Keep forecasting methods simple.
7.2 The forecasting method should provide a realistic representation of the situation.
7.3 Be conservative in situations of high uncertainty or instability.
7.4 Do not forecast cycles.

Implementing Quantitative Methods:

9.1 Tailor the forecasting model to the horizon.
9.2 Match the model to the underlying phenomena.
9.3 Do not use "fit" to develop the model.
9.5 Update models frequently.

Implementing Methods: Quantitative Models with Explanatory Variables:

10.2 Use all important variables.
10.5 Use different types of data to measure a relationship.
10.7 Forecast for alternate interventions.
10.9 Shrink the forecasts of change if there is high uncertainty for predictions of the explanatory variables.

Integrating Judgmental and Quantitative Methods:

11.1 Use structured procedures to integrate judgmental and quantitative methods.
11.2 Use structured judgment as inputs to quantitative models.
11.3 Use pre-specified domain knowledge in selecting, weighting, and modifying quantitative methods.

Combining Forecasts:

12.1 Combine forecasts from approaches that differ.
12.2 Use many approaches (or forecasters), preferably at least five.
12.3 Use formal procedures to combine forecasts.
12.8 Combine forecasts when there is uncertainty about which method is best.
12.9 Combine forecasts when you are uncertain about the situation.
12.10 Combine forecasts when it is important to avoid large errors.

Evaluating Methods:

13.1 Compare reasonable methods.
13.2 Use objective tests of assumptions.
13.3 Design test situations to match the forecasting problem.
13.5 Tailor the analysis to the decision.
13.6 Describe potential biases of forecasters.
13.7 Assess the reliability and validity of the data.
13.8 Provide easy access to the data.
13.10 Test assumptions for validity.
13.12 Use direct replications of evaluations to identify mistakes.
13.13 Replicate forecast evaluations to assess their reliability.
13.16 Compare forecasts generated by different methods.
13.17 Examine all important criteria.
13.18 Specify criteria for evaluating methods prior to analyzing data.
13.26 Use out-of-sample (ex ante) error measures.
13.27 Use ex post error measures to evaluate the effects of policy variables.
13.31 Base comparisons of methods on large samples of forecasts.

Assessing Uncertainty:

14.3 Develop prediction intervals by using empirical estimates based on realistic representations of forecasting situations.
14.5 Ensure consistency over the forecast horizon.
14.9 Combine prediction intervals from alternative forecasting methods.
14.10 Use safety factors to adjust for overconfidence in the PIs.
14.11 Conduct experiments to evaluate forecasts.
14.13 Incorporate the uncertainty associated with the prediction of the explanatory variables in the prediction intervals.
14.14 Ask for a judgmental likelihood that a forecast will fall within a pre-defined minimum-maximum interval (not by asking people to set upper and lower confidence levels).

Presenting Forecasts:

15.1 Present forecasts and supporting data in a simple and understandable form.
15.2 Provide complete, simple, and clear explanations of methods.

Table B: Principles apparently contravened in H6

Setting Objectives:

1.1 Describe decisions that might be affected by the forecasts.
1.2 Prior to forecasting, agree on actions to take assuming different possible forecasts.

Structuring the problem:

2.1 Identify possible outcomes prior to making forecasts.
2.3 Decompose the problem into parts.

Identify Data Sources:

3.2 Ensure that the data match the forecasting situation.
3.3 Avoid biased data sources.

Collecting Data:

4.2 Ensure that information is reliable and that measurement error is low.
4.3 Ensure that the information is valid.

Preparing Data:

5.3 Adjust intermittent series.
5.7 Damp seasonal factors for uncertainty
5.8 Use graphical displays for data.

Implementing Methods: General

7.6 Pool similar types of data.

Implementing Methods: Quantitative Models with Explanatory Variables:

10.4 Use theory and domain expertise to estimate or limit the magnitude of relationships.
10.8 Apply the same principles to forecasts of explanatory variables.

Evaluating Methods:

13.4 Describe conditions associated with the forecasting problem.
13.9 Provide full disclosure of methods.

Assessing Uncertainty:

14.6 Describe reasons why the forecasts might be wrong.
14.7 When assessing PIs, list possible outcomes and assess their likelihoods.
14.8 Obtain good feedback about forecast accuracy and the reasons why errors occurred.

Table C: Principles not rated due to lack of information in H6

Setting Objectives:

1.5 Obtain decision makers' agreement on methods

Structuring the problem:

2.7 Decompose time series by level and trend

Identify Data Sources:

3.1 Use theory to guide the search for information on explanatory variables

Collecting Data:

4.1 Use unbiased and systematic procedures to collect data
4.5 Avoid the collection of irrelevant data

Preparing Data:

5.1 Clean the data

Selecting Methods:

6.4 Use quantitative methods rather than qualitative methods
6.5 Use causal methods rather than naive methods if feasible
6.9 Assess acceptability and understandability of methods to users

Evaluating Methods:

13.11 Test the client's understanding of the methods
13.19 Assess face validity

Presenting Forecasts:

15.3 Describe your assumptions

Learning That Will Improve Forecasting Procedures:

16.2 Seek feedback about forecasts
16.3 Establish a formal review process for forecasting methods
16.4 Establish a formal review process to ensure that forecasts are used properly

Notes

1) Our interest in the topic of this paper was piqued when the State of Alaska hired us as consultants in late-September 2007 to assess forecasts that had been prepared "to Support U.S. Fish and Wildlife Service Polar Bear Listing Decision." We were impressed by the importance of the issue and, after providing our assessment, we decided to continue working on it and to prepare a paper for publication. These latter efforts have not been funded. We take responsibility for all judgments and for any errors that we might have made.

2) On November 27, 2007, we sent a draft of our paper to the authors of the U.S. Geological Survey administrative reports that we audited and stated:

> "As we note in our paper, there are elements of subjectivity in making the audit ratings. Should you feel that any of our ratings were incorrect, we would be grateful if you would you provide us with evidence that would lead to a different assessment. The same goes for any principle that you think does not apply, or to any principles that we might have overlooked. There are some areas that we could not rate due to a lack of information. Should you have information on those topics, we would be interested.

Finally, we would be interested in peer review that you or your colleagues could provide, and in suggestions on how to improve the accuracy and clarity of our paper."

We received a reply from Steven C. Amstrup on November 30, 2007 that said: "We all decline to offer preview comments on your attached manuscript. Please feel free, however, to list any of us as potential referees when you submit your manuscript for publication."

3) We invite others to conduct forecasting audits of AMD, H6, any of the other papers prepared to support the endangered species listing, or any other papers relevant to long-term forecasting of the polar bear population. Note that the audit process calls for two or more raters. The audits can be submitted for publication on pubicpolicyforecasting.com along with the auditors' bios and any information relevant potential sources of bias.

4) We seek information about scientifically developed forecasting studies, published or unpublished, that are relevant to polar bear forecasting.

5) We seek further peer review on this paper.

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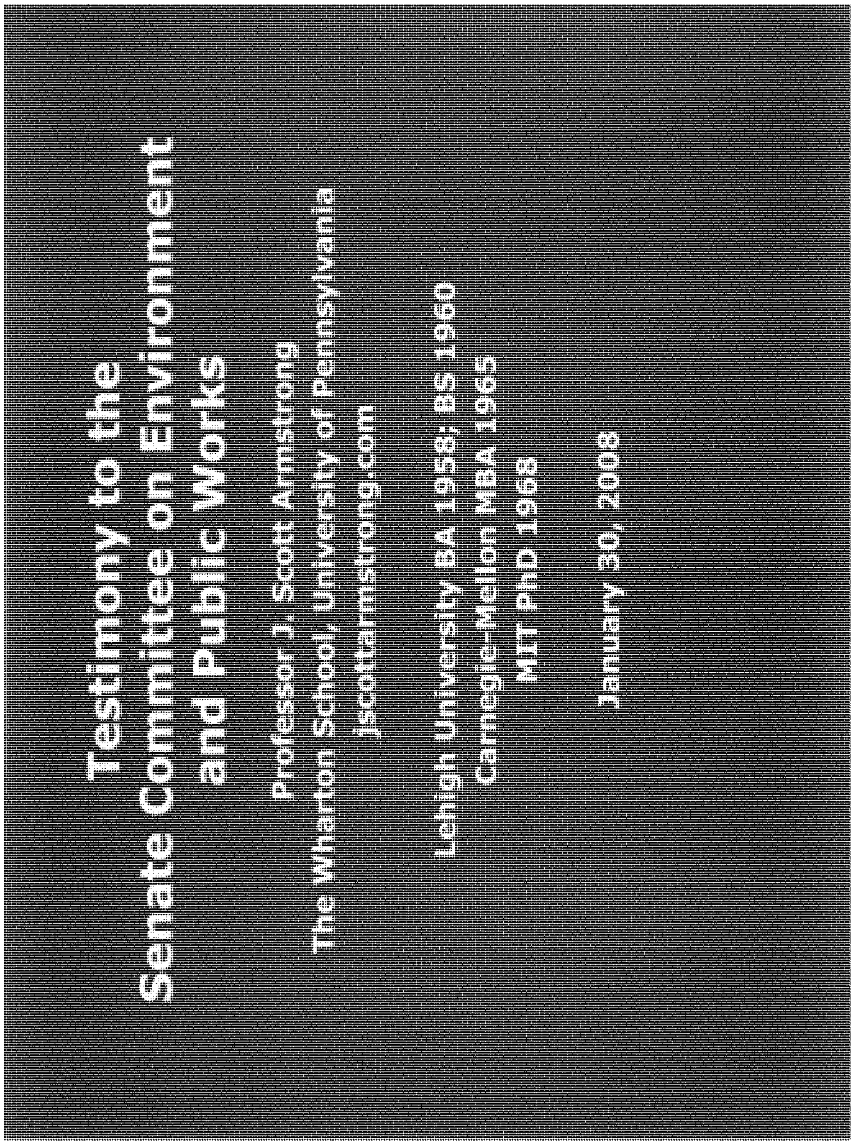
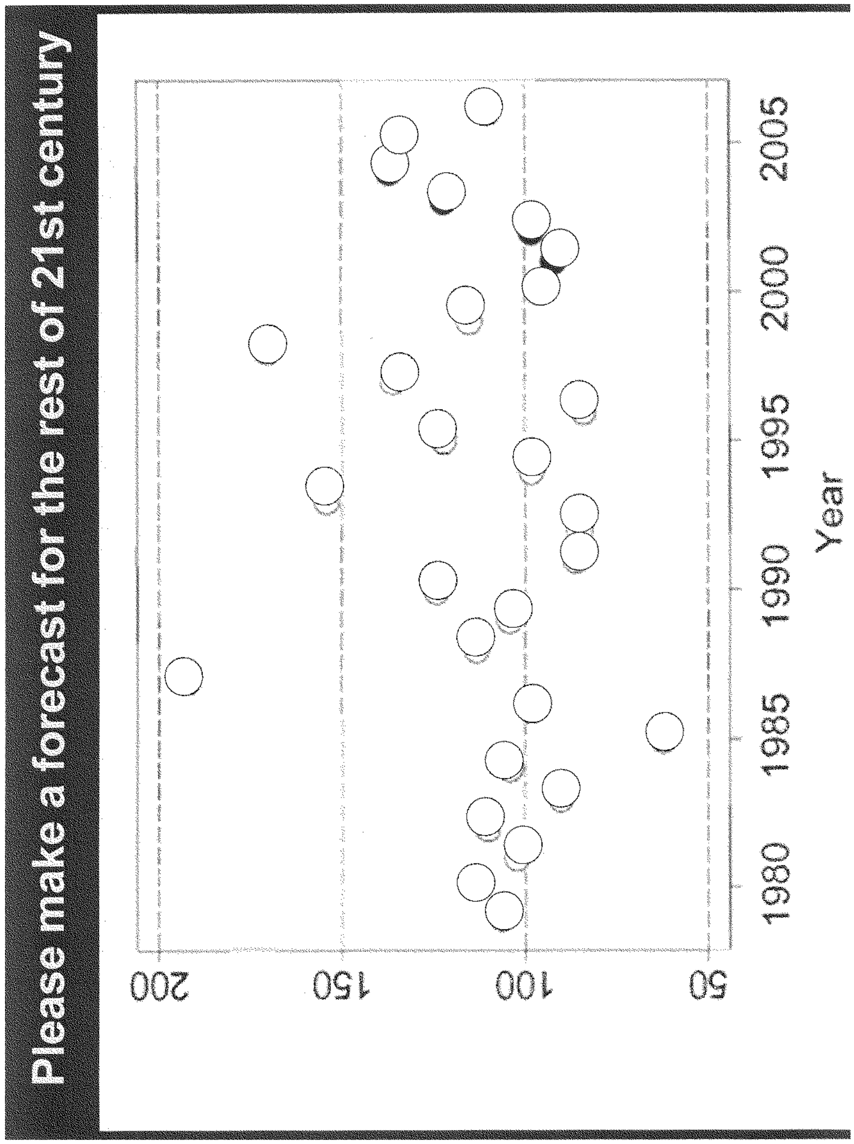

Testimony to the
Senate Committee on Environment
and Public Works
Professor J. Scott Armstrong
The Wharton School, University of Pennsylvania
jscottarmstrong.com
Lehigh University BA 1958; BS 1960
Carnegie-Mellon MBA 1965
MIT PhD 1968
January 30, 2008


Please make a forecast for the rest of 21st century
200
150
100
50
1980
1985
1990
1995
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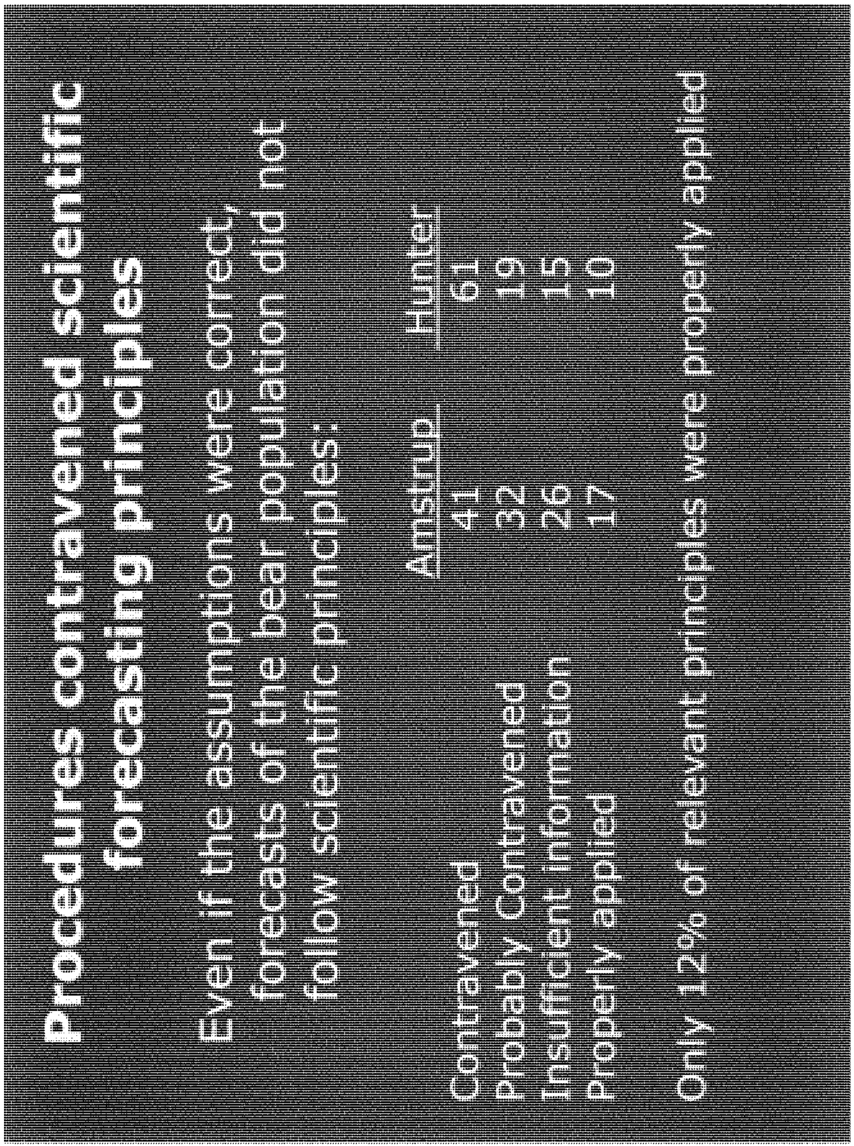
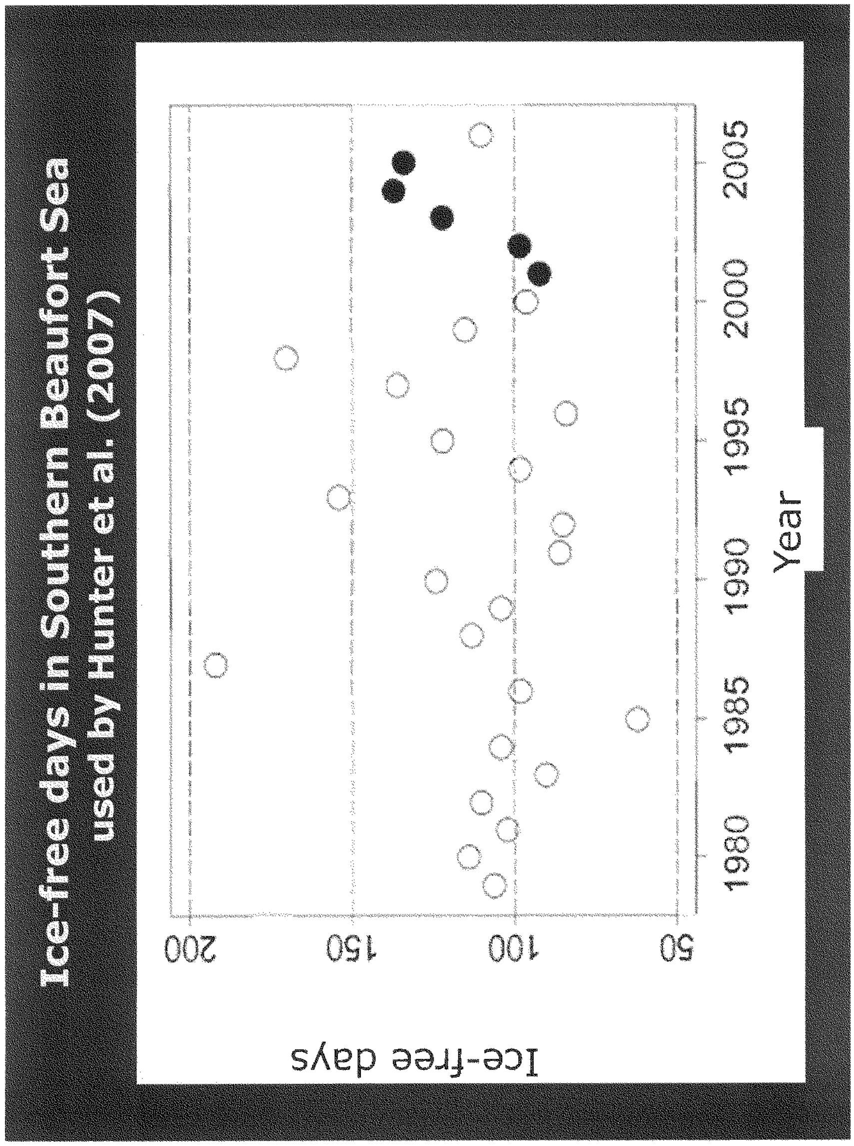
Year


Procedures contravened scientific forecasting principles
Even if the assumptions were correct, forecasts of the bear population did not follow scientific principles:
Amstrup Hunter
Contravened 41 61
Probably Contravened 32 19
Insufficient information 26 15
Properly applied 17 10
Only 12% of relevant principles were properly applied



Ice-free days in Southern Beaufort Sea
used by Hunter et al. (2007)
Ice-free days
200
150
100
50
1980
1985
1990
1995
2000
2005
Year

Possible solutions

1) Use a variety of forecasting methods

2) Generate a list of alternative solutions and prepare forecasts for each of them.

3) Commission forecasts by independent teams.

4) Promote collaboration among polar bear/climate experts along with forecasting experts

5) Require that all forecasts be based on audited methods that are open to public inspection. Any contraventions must be justified.

6) Combine forecasts that pass the audits.

GLOBAL WARMING: FORECASTS BY SCIENTISTS VERSUS SCIENTIFIC FORECASTS*

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ABSTRACT

In 2007, the Intergovernmental Panel on Climate Change's Working Group One, a panel of experts established by the World Meteorological Organization and the United Nations Environment Programme, issued its Fourth Assessment Report. The Report included predictions of dramatic increases in average world temperatures over the next 92 years and serious harm resulting from the predicted temperature increases. Using forecasting principles as our guide we asked: Are these forecasts a good basis for developing public policy? Our answer is "no".

To provide forecasts of climate change that are useful for policy-making, one would need to forecast (1) global temperature, (2) the effects of any temperature changes, and (3) the effects of feasible alternative policies. Proper forecasts of all three are necessary for rational policy making.

The IPCC WG1 Report was regarded as providing the most credible long-term forecasts of global average temperatures by 31 of the 51 scientists and others involved in forecasting climate change who responded to our survey. We found no references in the 1056-page Report to the primary sources of information on forecasting methods despite the fact these are conveniently available in books, articles, and websites. We audited the forecasting processes described in Chapter 8 of the IPCC's WG1 Report to assess the extent to which they complied with forecasting principles. We found enough information to make judgments on 89 out of a total of 140 forecasting principles. The forecasting procedures that were described violated 72 principles. Many of the violations were, by themselves, critical.

The forecasts in the Report were not the outcome of scientific procedures. In effect, they were the opinions of scientists transformed by mathematics and obscured by complex writing. Research on forecasting has shown that experts' predictions are not useful in situations involving uncertainly and complexity. We have been unable to identify any scientific forecasts of global warming. Claims that the Earth will get warmer have no more credence than saying that it will get colder.

Keywords: accuracy, audit, climate change, evaluation, expert judgment, mathematical models, public policy.

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†Information about J. Scott Armstrong can be found on Wikipedia.

"A trend is a trend,
But the question is, will it bend?
Will it alter its course
Through some unforeseen force
And come to a premature end?"
Alec Cairncross, 1969

Research on forecasting has been conducted since the 1930s. Empirical studies that compare methods in order to determine which ones provide the most accurate forecasts in specified situations are the most useful source of evidence. Findings, along with the evidence, were first summarized in Armstrong (1978, 1985). In the mid-1990s, the Forecasting Principles Project was established with the objective of summarizing all useful knowledge about forecasting. The knowledge was codified as evidence-based principles, or condition-action statements, in order to provide guidance on which methods to use when. The project led to the *Principles of Forecasting* handbook (Armstrong 2001): the work of 40 internationally-known experts on forecasting methods and 123 reviewers who were also leading experts on forecasting methods. The summarizing process alone required a four-year effort.

The forecasting principles are easy to find: They are freely available on forecastingprinciples.com, a site sponsored by the International Institute of Forecasters. The Forecasting Principles site has been at the top of the list of sites in Internet searches for "forecasting" for many years. A summary of the principles, currently numbering 140, is provided as a checklist in the Forecasting Audit software available on the site. The site is often updated in order to incorporate new evidence on forecasting as it comes to hand. A recent review of new evidence on some of the key principles was published in Armstrong (2006). There is no other source that provides evidence-based forecasting principles.

The strength of evidence is different for different principles, for example some principles are based on common sense or received wisdom. Such principles are included when there is no contrary evidence. Other principles have some empirical support, while 31 are strongly supported by empirical evidence.

Many of the principles go beyond common sense, and some are counter-intuitive. As a result, those who forecast in ignorance of the forecasting research literature are unlikely to produce useful predictions. Here are some well-established principles that apply to long-term forecasts for complex situations where the causal factors are subject to uncertainty (as with climate):

- *Unaided judgmental forecasts by experts have no value.* This applies whether the opinions are expressed in words, spreadsheets, or mathematical models. It applies regardless of how much scientific evidence is possessed by the experts. Among the reasons for this are:
  - a) Complexity: People cannot assess complex relationships through unaided observations.
  - b) Coincidence: People confuse correlation with causation.
  - c) Feedback: People making judgmental predictions typically do not

receive unambiguous feedback they can use to improve their forecasting.

d) Bias: People have difficulty in obtaining or using evidence that contradicts their initial beliefs. This problem is especially serious for people who view themselves as experts.

- *Agreement among experts is weakly related to accuracy.* This is especially true when the experts communicate with one another and when they work together to solve problems, as is the case with the IPCC process.
- *Complex models (those involving nonlinearities and interactions) harm accuracy because their errors multiply.* Ascher (1978), refers to the Club of Rome's 1972 forecasts where, unaware of the research on forecasting, the developers proudly proclaimed, "in our model about 100,000 relationships are stored in the computer." Complex models also tend to fit random variations in historical data well, with the consequence that they forecast poorly and lead to misleading conclusions about the uncertainty of the outcome. Finally, when complex models are developed there are many opportunities for errors and the complexity means the errors are difficult to find. Craig, Gadgil, and Koomey (2002) came to similar conclusions in their review of long-term energy forecasts for the US that were made between 1950 and 1980.
- *Given even modest uncertainty, prediction intervals are enormous.* Prediction intervals (ranges outside which outcomes are unlikely to fall) expand rapidly as time horizons increase, for example, so that one is faced with enormous intervals even when trying to forecast a straightforward thing such as automobile sales for General Motors over the next five years.
- *When there is uncertainty in forecasting, forecasts should be conservative.* Uncertainty arises when data contain measurement errors, when the series are unstable, when knowledge about the direction of relationships is uncertain, and when a forecast depends upon forecasts of related (causal) variables. For example, forecasts of no change were found to be more accurate than trend forecasts for annual sales when there was substantial uncertainty in the trend lines (Schnaars and Bavuso 1986). This principle also implies that forecasts should revert to long-term trends when such trends have been firmly established, do not waver, and there are no firm reasons to suggest that they will change. Finally, trends should be damped toward no-change as the forecast horizon increases.

THE FORECASTING PROBLEM

In determining the best policies to deal with the climate of the future, a policy maker first has to select an appropriate statistic to use to represent the changing climate. By convention, the statistic is the averaged global temperature as measured with thermometers at ground stations throughout the world, though in practice this is a far from satisfactory metric (see, e.g., Essex et al., 2007).

It is then necessary to obtain forecasts and prediction intervals for each of the following:

1. *Mean global temperature in the long-term (say 10 years or longer).*
2. *Effects of temperature changes on humans and other living things.*
   If accurate forecasts of mean global temperature can be obtained *and* the changes are substantial, *then* it would be necessary to forecast the effects of the changes on the health of living things and on the health and wealth of humans. The concerns about changes in global mean temperature are based on the assumption that the earth is currently at the optimal temperature and that variations over years (unlike variations within days and years) are undesirable. For a proper assessment, costs and benefits must be comprehensive. (For example, policy responses to Rachel Carson's *Silent Spring* should have been based in part on forecasts of the number of people who might die from malaria if DDT use were reduced).
3. *Costs and benefits of feasible alternative policy proposals.*
   If valid forecasts of the effects of the temperature changes on the health of living things and on the health and wealth of humans can be obtained *and* the forecasts are for substantial harmful effects, *then* it would be necessary to forecast the costs and benefits of proposed alternative policies that could be successfully implemented.

A policy proposal should only be implemented *if* valid and reliable forecasts of the effects of implementing the policy can be obtained *and* the forecasts show net benefits. Failure to obtain a valid forecast in any of the three areas listed above would render forecasts for the other areas meaningless. We address primarily, but not exclusively, the first of the three forecasting problems: obtaining long-term forecasts of global temperature.

But is it necessary to use scientific forecasting methods? In other words, to use methods that have been shown by empirical validation to be relevant to the types of problems involved with climate forecasting? Or is it sufficient to have leading scientists examine the evidence and make forecasts? We address this issue before moving on to our audits.

ON THE VALUE OF FORECASTS BY EXPERTS

Many public policy decisions are based on forecasts by experts. Research on persuasion has shown that people have substantial faith in the value of such forecasts. Faith increases when experts agree with one another.

Our concern here is with what we refer to as unaided expert judgments. In such cases, experts may have access to empirical studies and other information, but they use their knowledge to make predictions without the aid of well-established forecasting principles. Thus, they could simply use the information to come up with judgmental forecasts. Alternatively, they could translate their beliefs into mathematical statements (or models) and use those to make forecasts.

Although they may seem convincing at the time, expert forecasts can make for humorous reading in retrospect. Cerf and Navasky's (1998) book contains 310 pages of examples, such as Fermi Award-winning scientist John von Neumann's 1956 prediction that "A few decades hence, energy may be free". Examples of expert climate forecasts that turned out to be completely wrong are easy to find, such as UC Davis ecologist Kenneth Watt's prediction in a speech at Swarthmore College on Earth Day, April 22, 1970:

> If present trends continue, the world will be about four degrees colder in 1990, but eleven degrees colder in the year 2000. This is about twice what it would take to put us into an ice age.

Are such examples merely a matter of selective perception? The second author's review of empirical research on this problem led him to develop the "Seer-sucker theory," which can be stated as "No matter how much evidence exists that seers do not exist, seers will find suckers" (Armstrong 1980). The amount of expertise does not matter beyond a basic minimum level. There are exceptions to the Seer-sucker Theory: When experts get substantial well-summarized feedback about the accuracy of their forecasts and about the reasons why their forecasts were or were not accurate, they can improve their forecasting. This situation applies for short-term (up to five day) weather forecasts, but we are not aware of any such regime for long-term global climate forecasting. Even if there were such a regime, the feedback would trickle in over many years before it became useful for improving forecasting.

Research since 1980 has provided much more evidence that expert forecasts are of no value. In particular, Tetlock (2005) recruited 284 people whose professions included, "commenting or offering advice on political and economic trends." He asked them to forecast the probability that various situations would or would not occur, picking areas (geographic and substantive) within and outside their areas of expertise. By 2003, he had accumulated over 82,000 forecasts. The experts barely if at all outperformed non-experts and neither group did well against simple rules.

Comparative empirical studies have routinely concluded that judgmental forecasting by experts is the least accurate of the methods available to make forecasts. For example, Ascher (1978, p. 200), in his analysis of long-term forecasts of electricity consumption found that was the case.

Experts' forecasts of climate changes have long been newsworthy and a cause of worry for people. Anderson and Gainor (2006) found the following headlines in their search of the *New York Times*:

Sept. 18, 1924	MacMillan Reports Signs of New Ice Age
March 27, 1933	America in Longest Warm Spell Since 1776
May 21, 1974	Scientists Ponder Why World's Climate is Changing: A Major Cooling Widely Considered to be Inevitable
Dec. 27, 2005	Past Hot Times Hold Few Reasons to Relax About New Warming

In each case, the forecasts behind the headlines were made with a high degree of confidence.

In the mid-1970s, there was a political debate raging about whether the global climate was changing. The United States' National Defense University (NDU) addressed this issue in their book, *Climate Change to the Year* 2000 (NDU 1978). This study involved nine man-years of effort by the Department of Defense and other agencies, aided by experts who received honoraria, and a contract of nearly $400,000 (in 2007 dollars). The heart of the study was a survey of experts. The experts were provided with a chart of "annual mean temperature, 0-80^0 N. latitude," that showed temperature rising from 1870 to early 1940 then dropping sharply until 1970. The conclusion, based primarily on 19 replies weighted by the study directors, was that while a slight increase in temperature might occur, uncertainty was so high that "the next twenty years will be similar to that of the past" and the effects of any change would be negligible. Clearly, this was a forecast by scientists, not a scientific forecast. However, it proved to be quite influential. The report was discussed in The Global 2000 Report to the President (Carter) and at the World Climate Conference in Geneva in 1979.

The methodology for climate forecasting used in the past few decades has shifted from surveys of experts' opinions to the use of computer models. Reid Bryson, the world's most cited climatologist, wrote in a 1993 article that a model is "*nothing more* than a formal statement of how the modeler believes that the part of the world of his concern actually works" (p. 798-790). Based on the explanations of climate models that we have seen, we concur. While advocates of complex climate models claim that they are based on "well established laws of physics", there is clearly much more to the models than the laws of physics otherwise they would all produce the same output, which patently they do not. And there would be no need for confidence estimates for model forecasts, which there most certainly are. Climate models are, in effect, mathematical ways for the experts to express their opinions.

To our knowledge, there is no empirical evidence to suggest that presenting opinions in mathematical terms rather than in words will contribute to forecast accuracy. For example, Keepin and Wynne (1984) wrote in the summary of their study of the International Institute for Applied Systems Analysis's "widely acclaimed" projections for global energy that "Despite the appearance of analytical rigor... [they] are highly unstable and based on informal guesswork." Things have changed little since the days of Malthus in the 1800s. Malthus forecast mass starvation. He expressed his opinions mathematically. His mathematical model predicted that the supply of food would increase arithmetically while the human population grew at a geometric rate and went hungry.

International surveys of climate scientists from 27 countries, obtained by Bray and von Storch in 1996 and 2003, were summarized by Bast and Taylor (2007). Many scientists were skeptical about the predictive validity of climate models. Of more than 1,060 respondents, 35% agreed with the statement, "Climate models can accurately predict future climates," and 47% percent disagreed. Members of the general public were also divided. An Ipsos Mori poll of 2,031 people aged 16 and over found that 40% agreed that "climate change was too complex and uncertain for scientists to make useful forecasts" while 38% disagreed (Eccleston 2007).

AN EXAMINATION OF CLIMATE FORECASTING METHODS

We assessed the extent to which those who have made climate forecasts used evidence-based forecasting procedures. We did this by conducting Google searches. We then conducted a "forecasting audit" of the forecasting process behind the IPCC forecasts. The key tasks of a forecasting audit are to:

- examine all elements of the forecasting process,
- use principles that are supported by evidence (or are self-evidently true and unchallenged by evidence) against which to judge the forecasting process,
- rate the forecasting process against each principle, preferably using more than one independent rater,
- disclose the audit.

To our knowledge, no one has ever published a paper that is based on a forecasting audit, as defined here. We suggest that for forecasts involving important public policies, such audits should be expected and perhaps even-required. In addition, they should be fully disclosed with respect to who did the audit, what biases might be involved, and what were the detailed findings from the audit.

REVIEWS OF CLIMATE FORECASTS

We could not find any *comprehensive* reviews of climate forecasting efforts. With the exception of Stewart and Glantz (1985), the reviews did not refer to evidence-based findings. None of the reviews provided explicit ratings of the processes and, again with the exception of Stewart and Glantz, little attention was given to full disclosure of the reviewing process. Finally, some reviews ignored the forecasting methods and focused on the accuracy of the forecasts.

Stewart and Glantz (1985) conducted an audit of the National Defense University (NDU 1978) forecasting process that we described above. They were critical of the report because it lacked an awareness of proper forecasting methodology. Their audit was hampered because the organizers of the study said that the raw data had been destroyed and a request to the Institute for the Future about the sensitivity of the forecasts to the weights went unanswered. Judging from a Google Scholar search, climate forecasters have paid little attention to this paper.

In a wide-ranging article on the broad topic of science and the environment, Bryson (1993) was critical of the use of models for forecasting climate. He wrote:

> ...it has never been demonstrated that the GCMs [General Circulation Models] are capable of prediction with any level of accuracy. When a modeler says that his model shows that doubling the carbon dioxide in the atmosphere will raise the global average temperature two to three degrees Centigrade, he really means that a simulation of the present global temperature with current carbon dioxide levels yields a mean value two to three degrees Centigrade lower than his model simulation with doubled carbon dioxide. This implies, though it rarely appears in the news media, that the error in simulating the present will be unchanged in simulating the future case with doubled carbon dioxide. That has never been demonstrated—it is faith rather than science." (pp. 790-791)

Balling (2005), Christy (2005), Frauenfeld (2005), and Posmentier and Soon (2005) each assess different aspects of the use of climate models for forecasting and each comes to broadly the same conclusion: The models do not represent the real world sufficiently well to be relied upon for forecasting.

Carter, et al. (2006) examined the *Stern Review* (Stern 2007). They concluded that the authors of the *Review* made predictions without reference to scientific validation and without proper peer review.

Pilkey and Pilkey-Jarvis (2007) examined long-term climate forecasts and concluded that they were based only on the opinions of the scientists. The scientists' opinions were expressed in complex mathematical terms without evidence on the validity of chosen approach. The authors provided the following quotation on their page 45 to summarize their assessment: "Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation and eventually build a structure which has no relation to reality (Nikola Telsa, inventor and electrical engineer, 1934)." While it is sensible to be explicit about beliefs and to formulate these in a model, forecasters must also demonstrate that the relationships are valid.

Carter (2007) examined evidence on the predictive validity of the general circulation models (GCMs) used by the IPCC scientists. He found that while the models included some basic principles of physics, scientists had to make "educated guesses" about the values of many parameters because knowledge about the physical processes of the earth's climate is incomplete. In practice, the GCMs failed to predict recent global average temperatures as accurately as simple curve-fitting approaches (Carter 2007, pp. 64 – 65). They also forecast greater warming at higher altitudes in the tropics when the opposite has been the case (p. 64). Further, individual GCMs produce widely different forecasts from the same initial conditions and minor changes in parameters can result in forecasts of global cooling (Essex and McKitrick, 2002). Interestingly, when models predict global cooling, the forecasts are often rejected as "outliers" or "obviously wrong" (e.g., Stainforth et al., 2005).

Roger Pielke Sr. (Colorado State Climatologist, until 2006) gave an assessment of climate models in a 2007 interview (available via http://tinyurl.com/2wpk29):

> You can always reconstruct after the fact what happened if you run enough model simulations. The challenge is to run it on an independent dataset, say for the next five years. But then they will say "the model is not good for five years because there is too much noise in the system". That's avoiding the issue then. They say you have to wait 50 years, but then you can't validate the model, so what good is it?
>
> ...Weather is very difficult to predict; climate involves weather plus all these other components of the climate system, ice, oceans, vegetation, soil etc. Why should we think we can do better with climate prediction than with weather prediction? To me it's obvious, we can't!
>
> I often hear scientists say "weather is unpredictable, but climate you can predict because it is the average weather". How can they prove such a statement?

In his assessment of climate models, physicist Freeman Dyson (2007) wrote:

> I have studied the climate models and I know what they can do. The models solve

> the equations of fluid dynamics, and they do a very good job of describing the fluid motions of the atmosphere and the oceans. They do a very poor job of describing the clouds, the dust, the chemistry and the biology of fields and farms and forests. They do not begin to describe the real world that we live in.

Bellamy and Barrett (2007) found serious deficiencies in the general circulation models described in the IPCC's *Third Assessment Report*. In particular, the models (1) produced very different distributions of clouds and none was close the actual distribution of clouds, (2) parameters for incoming radiation absorbed by the atmosphere and for that absorbed by the Earth's surface varied considerably, (3) did not accurately represent what is known about the effects of CO_2 and could not represent the possible positive and negative feedbacks about which there is great uncertainty. The authors concluded:

> The climate system is a highly complex system and, to date, no computer models are sufficiently accurate for their predictions of future climate to be relied upon. (p. 72)

Trenberth (2007), a lead author of Chapter 3 in the IPCC WG1 report wrote in a *Nature.com* blog "... the science is not done because we do not have reliable or regional predictions of climate."

Taylor (2007) compared seasonal forecasts by New Zealand's National Institute of Water and Atmospheric Research (NIWA) with outcomes for the period May 2002 to April 2007. He found NIWA's forecasts of average regional temperatures for the season ahead were 48% correct, which was no more accurate than chance. That this is a general result was confirmed by New Zealand climatologist Jim Renwick, who observed that NIWA's low success rate was comparable to that of other forecasting groups worldwide. He added that "Climate prediction is hard, half of the variability in the climate system is not predictable, and so we don't expect to do terrifically well." Renwick is a co-author with Working Group I of the IPCC 4th Assessment Report, and also serves on the World Meteorological Organization Commission for Climatology Expert Team on Seasonal Forecasting. His expert view is that current GCM climate models are unable to predict future climate any better than chance (New Zealand Climate Science Coalition 2007).

Similarly, Vizard, Anderson, and Buckley (2005) found seasonal rainfall forecasts for Australian townships were insufficiently accurate to be useful to intended consumers such as farmers planning for feed requirements. The forecasts were released only 15 days ahead of each three month period.

A SURVEY TO IDENTIFY THE MOST CREDIBLE LONG-TERM FORECASTS OF GLOBAL TEMPERATURE

We surveyed scientists involved in long-term climate forecasting and policy makers. Our primary concern was to identify the most important forecasts and how those forecasts were made. In particular, we wished to know if the most widely accepted forecasts of global average temperature were based on the opinions of experts or were derived using scientific forecasting methods. Given the findings of our review of reviews of climate forecasting and the conclusion from our Google search that many scientists are unaware of evidence-based findings related to forecasting methods, we expected that the forecasts would be based on the opinions of scientists.

We sent a questionnaire to experts who had expressed diverse opinions on global warming. We generated lists of experts by identifying key people and asking them to identify others. (The lists are provided in Appendix A.) Most (70%) of the 240 experts on our lists were IPCC reviewers and authors.

Our questionnaire asked the experts to provide references for what they regarded as the most credible source of long-term forecasts of mean global temperatures. We strove for simplicity to minimize resistance to our request. Even busy people should have time to send a few references, especially if they believe that it is important to evaluate the quality of the forecasts that may influence major decisions. We asked:

> "We want to know which forecasts people regard as the most credible and how those forecasts were derived...
>
> In your opinion, which scientific article is the source of the most credible forecasts of global average temperatures over the rest of this century?"

We received useful responses from 51 of the 240 experts, 42 of whom provided references to what they regarded as credible sources of long-term forecasts of mean global temperatures. Interestingly, eight respondents provided references in support of their claims that no credible forecasts exist. Of the 42 expert respondents who were associated with global warming views, 30 referred us to the IPCC's report. A list of the papers that were suggested by respondents is provided at publicpolicyforecasting.com in the "Global Warming" section.

Based on the replies to our survey, it was clear that the IPCC's Working Group 1 Report contained the forecasts that are viewed as most credible by the bulk of the climate forecasting community. These forecasts are contained in Chapter 10 of the Report and the models that are used to forecast climate are assessed in Chapter 8, "Climate Models and Their Evaluation" (Randall et al. 2007). Chapter 8 provided the most useful information on the forecasting process used by the IPCC to derive forecasts of mean global temperatures, so we audited that chapter.

We also posted calls on email lists and on the forecastingprinciples.com site asking for help from those who might have any knowledge about scientific climate forecasts. This yielded few responses, only one of which provided relevant references.

Does the IPCC report provide climate forecasts?

Trenberth (2007) and others have claimed that the IPCC does not provide forecasts but rather presents "scenarios" or "projections." As best as we can tell, these terms are used by the IPCC authors to indicate that they provide "conditional forecasts." Presumably the IPCC authors hope that readers, especially policy makers, will find at least one of their conditional forecast series plausible and will act as if it will come true if no action is taken. As it happens, the word "forecast" and its derivatives occurred 37 times, and "predict" and its derivatives occurred 90 times in the body of

Chapter 8. Recall also that most of our respondents (29 of whom were IPCC authors or reviewers) nominated the IPCC report as the most credible source of forecasts (not "scenarios" or "projections") of global average temperature. We conclude that the IPCC does provide forecasts.

A FORECASTING AUDIT FOR GLOBAL WARMING

In order to audit the forecasting processes described in Chapter 8 of the IPCC's report, we each read it prior to any discussion. The chapter was, in our judgment, poorly written. The writing showed little concern for the target readership. It provided extensive detail on items that are of little interest in judging the merits of the forecasting process, provided references without describing what readers might find, and imposed an incredible burden on readers by providing 788 references. In addition, the Chapter reads in places like a sales brochure. In the three-page executive summary, the terms, "new" and "improved" and related derivatives appeared 17 times. Most significantly, the chapter omitted key details on the assumptions and the forecasting process that were used. If the authors used a formal structured procedure to assess the forecasting processes, this was not evident.

We each made a formal, independent audit of IPCC Chapter 8 in May 2007. To do so, we used the Forecasting Audit Software on the forecastingprinciples.com site, which is based on material originally published in Armstrong (2001). To our knowledge, it is the only evidence-based tool for evaluating forecasting procedures.

While Chapter 8 required many hours to read, it took us each about one hour, working independently, to rate the forecasting approach described in the Chapter using the Audit software. We have each been involved with developing the Forecasting Audit program, so other users would likely require much more time.

Ratings are on a 5-point scale from -2 to +2. A rating of +2 indicates the forecasting procedures were consistent with a principle, and a rating of -2 indicates failure to comply with a principle. Sometimes some aspects of a procedure are consistent with a principle but others are not. In such cases, the rater must judge where the balance lays. The Audit software also has options to indicate that there is insufficient information to rate the procedures or that the principle is not relevant to a particular forecasting problem.

Reliability is an issue with rating tasks. For that reason, it is desirable to use two or more raters. We sent out general calls for experts to use the Forecasting Audit Software to conduct their own audits and we also asked a few individuals to do so. At the time of writing, none have done so.

Our initial overall average ratings were similar at -1.37 and -1.35. We compared our ratings for each principle and discussed inconsistencies. In some cases we averaged the ratings, truncating toward zero. In other cases we decided that there was insufficient information or that the information was too ambiguous to rate with confidence. Our final ratings are fully disclosed in the Special Interest Group section of the forecastingprinciples.com site that is devoted to Public Policy (publicpolicyforecasting.com) under Global Warming.

Of the 140 principles in the Forecasting Audit, we judged that 127 were relevant for auditing the forecasting procedures described in Chapter 8. The Chapter provided insufficient information to rate the forecasting procedures that were used against 38 of

Table 1. Clear Violations

Setting Objectives
- Describe decisions that might be affected by the forecast.
- Prior to forecasting, agree on actions to take assuming different possible forecasts.
- Make sure forecasts are independent of politics.
- Consider whether the events or series can be forecasted.

Identifying Data Points
- Avoid biased data sources.

Collecting Data
- Use unbiased and systematic procedures to collect data.
- Ensure that information is reliable and that measurement error is low.
- Ensure that the information is valid.

Selecting Methods
- List all important selection criteria before selecting methods.
- Ask unbiased experts to rate potential methods.
- Select simple methods unless empirical evidence calls for a more complex approach.
- Compare track records of various forecasting methods.
- Assess acceptability and understandability of methods to users
- Examine the value of alternative forecasting methods.

Implementing Methods: General
- Keep forecasting methods simple.
- Be conservative in situations of high uncertainty or instability.

Implementing Quantitative Methods
- Tailor the forecasting model to the horizon.
- Do not use "fit" to develop the model.

Implementing Methods: Quantitative Models with Explanatory Variables
- Apply the same principles to forecasts of explanatory variables.
- Shrink the forecasts of change if there is high uncertainty for predictions of the explanatory variables.

Integrating Judgmental and Quantitative Methods
- Use structured procedures to integrate judgmental and quantitative methods.
- Use structured judgments as inputs of quantitative models.
- Use prespecified domain knowledge in selecting, weighing, and modifying quantitative models.

Combining Forecasts
- Combine forecasts from approaches that differ.
- Use trimmed means, medians, or modes.
- Use track records to vary the weights on component forecasts.

Evaluating Methods
- Compare reasonable methods.
- Tailor the analysis to the decision.
- Describe the potential biases of the forecasters.
- Assess the reliability and validity of the data.
- Provide easy access to the data.
- Provide full disclosure of methods.
- Test assumptions for validity.
- Test the client's understanding of the methods.
- Use direct replications of evaluations to identify mistakes.
- Replicate forecast evaluations to assess their reliability.
- Compare forecasts generated by different methods.
- Examine all important criteria.
- Specify criteria for evaluating methods prior to analyzing data.
- Assess face validity.
- Use error measures that adjust for scale in the data.
- Ensure error measures are valid.
- Use error measures that are not sensitive to the degree of difficulty in forecasting.
- Avoid error measures that are highly sensitive to outliers.
- Use out of sample (ex-ante) error measures.
- (Revised) Tests of statistical significance should not be used.
- Do not use root mean square error (RMSE) to make comparisons among forecasting methods.
- Base comparisons of methods on large samples of forecasts.
- Conduct explicit cost-benefit analysis.

Assessing Uncertainty
- Use objective procedures to estimate explicit prediction.
- Develop prediction intervals by using empirical estimates based on realistic representations of forecasting situations.
- When assessing PIs, list possible outcomes and assess their likelihoods.
- Obtain good feedback about forecast accuracy and the reasons why errors occurred.
- Combine prediction intervals from alternative forecast methods.
- Use safety factors to adjust for overconfidence in PIs.

Presenting Forecasts
- Present forecasts and supporting data in a simple and understandable form.
- Provide complete, simple, and clear explanations of methods.
- Present prediction intervals.

Learning That Will Improve Forecasting Procedures
- Establish a formal review process for forecasting methods.
- Establish a formal review process to ensure that forecasts are used properly.

these 127 principles. For example, we did not rate the Chapter against Principle 10.2: "Use all important variables." At least in part, our difficulty in auditing the Chapter was due to the fact that it was abstruse. It was sometimes difficult to know whether the information we sought was present or not.

Of the 89 forecasting principles that we were able to rate, the Chapter violated 72. Of these, we agreed that there were clear violations of 60 principles. Principle 1.3 "Make sure forecasts are independent of politics" is an example of a principle that is clearly violated by the IPCC process. This principle refers to keeping the forecasting process separate from the planning process. The term "politics" is used in the broad sense of the exercise of power. David Henderson, a former Head of Economics and Statistics at the OECD, gave a detailed account of how the IPCC process is directed by non-scientists who have policy objectives and who believe that anthropogenic global warming is real and dangerous (Henderson 2007). The clear violations we identified are listed in Table 1.

We also found 12 "apparent violations". These principles, listed in Table 2, are ones for which one or both of us had some concerns over the coding or where we did not agree that the procedures clearly violated the principle.

Table 2. Apparent Violations

Setting Objectives
- Obtain decision makers' agreement on methods.

Structuring the Problem
- Identify possible outcomes prior to making forecast.
- Decompose time series by level and trend.

Identifying Data Sources
- Ensure the data match the forecasting situation.
- Obtain information from similar (analogous) series or cases. Such information may help to estimate trends.

Implementing Judgmental Methods
- Obtain forecasts from heterogeneous experts.

Evaluating Methods
- Design test situations to match the forecasting problem.
- Describe conditions associated with the forecasting problem.
- Use multiple measures of accuracy.

Assessing Uncertainty
- Do not assess uncertainty in a traditional (unstructured) group meeting.
- Incorporate the uncertainty associated with the prediction of the explanatory variables in the prediction intervals.

Presenting Forecasts
- Describe your assumptions.

Finally, we lacked sufficient information to make ratings on many of the relevant principles. These are listed in Table 3.

Table 3. Lack of Information

Structuring the Problem
- Tailor the level of data aggregation (or segmentation) to the decisions.
- Decompose the problem into parts.
- Decompose time series by causal forces.
- Structure problems to deal with important interactions among causal variables.
- Structure problems that involve causal chains.

Identifying Data Sources
- Use theory to guide the search for information on explanatory variables.

Collecting Data
- Obtain all the important data.
- Avoid collection of irrelevant data.

Preparing Data
- Clean the data.
- Use transformations as required by expectations.
- Adjust intermittent series.
- Adjust for unsystematic past events.
- Adjust for systematic events.
- Use graphical displays for data.

Implementing Methods: General
- Adjust for events expected in the future.
- Pool similar types of data.
- Ensure consistency with forecasts of related series and related time periods.

Implementing Judgmental Methods
- Ask experts to justify their forecasts in writing.
- Obtain forecasts from enough respondents.
- Obtain multiple forecasts of an event from each expert.

Implementing Quantitative Methods
- Match the model to the underlying phenomena.
- Weigh the most relevant data more heavily.
- Update models frequently.

Implementing Methods: Quantitative Models with Explanatory Variables
- Use all important variables.
- Rely on theory and domain expertise when specifying directions of relationships.
- Use theory and domain expertise to estimate or limit the magnitude of relationships.
- Use different types of data to measure a relationship.
- Forecast for alternative interventions.

Integrating Judgmental and Quantitative Methods
- Limit subjective adjustments of quantitative forecasts.

Combining Forecasts
- Use formal procedures to combine forecasts.
- Start with equal weights.
- Use domain knowledge to vary weights on component forecasts.

Table 3. *continued*

Evaluating Methods
- Use objective tests of assumptions.
- Avoid biased error measures.
- Do not use R-square (either standard or adjusted) to compare forecasting models.

Assessing Uncertainty
- Ensure consistency of the forecast horizon.
- Ask for a judgmental likelihood that a forecast will fall within a pre-defined minimum-maximum interval.

Learning That Will Improve Forecasting Procedures
- Seek feedback about forecasts.

Some of these principles might be surprising to those who have not seen the evidence—"Do not use R-square (either standard or adjusted) to compare forecasting models." Others are principles that any scientific paper should be expected to address—"Use objective tests of assumptions." Many of these principles are important for climate forecasting, such as "Limit subjective adjustments of quantitative forecasts."

Some principles are so important that any forecasting process that does not adhere to them cannot produce valid forecasts. We address four such principles, all of which are based on strong empirical evidence. All four of these key principles were violated by the forecasting procedures described in IPCC Chapter 8.

Consider whether the events or series can be forecasted (Principle 1.4)

This principle refers to whether a forecasting method can be used that would do better than a naïve method. A common naïve method is to assume that things will not change.

Interestingly, naïve methods are often strong competitors with more sophisticated alternatives. This is especially so when there is much uncertainty. To the extent that uncertainty is high, forecasters should emphasize the naïve method. (This is illustrated by regression model coefficients: when uncertainty increases, the coefficients tend towards zero.) Departures from the naïve model tend to increase forecast error when uncertainty is high.

In our judgment, the uncertainty about global mean temperature is extremely high. We are not alone. Dyson (2007), for example, wrote in reference to attempts to model climate that "The real world is muddy and messy and full of things that we do not yet understand." There is even controversy among climate scientists over something as basic as the current trend. One researcher, Carter (2007, p. 67) wrote:

> ...the slope and magnitude of temperature trends inferred from time-series data depend upon the choice of data end points. Drawing trend lines through highly variable, cyclic temperature data or proxy data is therefore a dubious exercise. Accurate direct measurements of tropospheric global average temperature have only been available since 1979, and they show no evidence for greenhouse warming. Surface thermometer data, though flawed, also show temperature stasis since 1998.

Global climate is complex and scientific evidence on key relationships is weak or absent. For example, does increased CO_2 in the atmosphere cause high temperatures or do high temperatures increase CO_2? In opposition to the major causal role assumed for CO_2 by the IPCC authors (Le Treut et al. 2007), Soon (2007) presents evidence that the latter is the case and that CO_2 variation plays at most a minor role in climate change.

Measurements of key variables such as local temperatures and a representative global temperature are contentious and subject to revision in the case of modern measurements because of inter alia the distribution of weather stations and possible artifacts such as the urban heat island effect, and are often speculative in the case of ancient ones, such as those climate proxies derived from tree ring and ice-core data (Carter 2007).

Finally, it is difficult to forecast the causal variables. Stott and Kettleborough (2002, p. 723) summarize:

> Even with perfect knowledge of emissions, uncertainties in the representation of atmospheric and oceanic processes by climate models limit the accuracy of any estimate of the climate response. Natural variability, generated both internally and from external forcings such as changes in solar output and explosive volcanic eruptions, also contributes to the uncertainty in climate forecasts.

The already high level of uncertainty rises rapidly as the forecast horizon increases.

While the authors of Chapter 8 claim that the forecasts of global mean temperature are well-founded, their language is imprecise and relies heavily on such words as "generally," "reasonable well," "widely," and "relatively" [to what?]. The Chapter makes many explicit references to uncertainty. For example, the phrases ". . . it is not yet possible to determine which estimates of the climate change cloud feedbacks are the most reliable" and "Despite advances since the TAR, substantial uncertainty remains in the magnitude of cryospheric feedbacks within AOGCMs" appear on p. 593. In discussing the modeling of temperature, the authors wrote, "The extent to which these systematic model errors affect a model's response to external perturbations is unknown, but may be significant" (p. 608), and, "The diurnal temperature range... is generally too small in the models, in many regions by as much as 50%" (p. 609), and "It is not yet known why models generally underestimate the diurnal temperature range." The following words and phrases appear at least once in the Chapter: unknown, uncertain, unclear, not clear, disagreement, not fully understood, appears, not well observed, variability, variety, unresolved, not resolved, and poorly understood.

Given the high uncertainty regarding climate, the appropriate naïve method for this situation would be the "no-change" model. Prior evidence on forecasting methods suggests that attempts to improve upon the naïve model might increase forecast error. To reverse this conclusion, one would have to produce validated evidence in favor of alternative methods. Such evidence is not provided in Chapter 8 of the IPCC report.

We are not suggesting that we know for sure that long-term forecasting of climate is impossible, only that this has yet to be demonstrated. Methods consistent with forecasting principles such as the naïve model with drift, rule-based forecasting, well-specified simple causal models, and combined forecasts might prove useful. The methods are discussed in Armstrong (2001). To our knowledge, their application to long-term climate forecasting has not been examined to date.

Keep forecasting methods simple (Principle 7.1)

We gained the impression from the IPPC chapters and from related papers that climate forecasters generally believe that complex models are necessary for forecasting climate and that forecast accuracy will increase with model complexity. Complex methods involve such things as the use of a large number of variables in forecasting models, complex interactions, and relationships that employ nonlinear parameters. Complex forecasting methods are only accurate when there is little uncertainty about relationships now and in the future, where the data are subject to little error, and where the causal variables can be accurately forecast. These conditions do not apply to climate forecasting. Thus, simple methods are recommended.

The use of complex models when uncertainty is high is at odds with the evidence from forecasting research (e.g., Allen and Fildes 2001, Armstrong 1985, Duncan, Gorr and Szczypula 2001, Wittink and Bergestuen 2001). Models for forecasting variations in climate are not an exception to this rule. Halide and Ridd (2007) compared predictions of El Niño-Southern Oscillation events from a simple univariate model with those from other researchers' complex models. Some of the complex models were dynamic causal models incorporating laws of physics. In other words, they were similar to those upon which the IPCC authors depended. Halide and Ridd's simple model was better than all eleven of the complex models in making predictions about the next three months. All models performed poorly when forecasting further ahead.

The use of complex methods makes criticism difficult and prevents forecast users from understanding how forecasts were derived. One effect of this exclusion of others from the forecasting process is to reduce the chances of detecting errors.

Do not use fit to develop the model (Principle 9.3)

It was not clear to us to what extent the models described in Chapter 8 (or in Chapter 9 by Hegerl et al. 2007) are either based on, or have been tested against, sound empirical data. However, some statements were made about the ability of the models to fit historical data, after tweaking their parameters. Extensive research has shown that the ability of models to fit historical data has little relationship to forecast accuracy (See "Evaluating forecasting methods" in Armstrong 2001.) It is well known that fit can be improved by making a model more complex. The typical consequence of increasing complexity to improve fit, however, is to decrease the accuracy of forecasts.

Use out-of-sample (ex ante) error measures (Principle 13.26)

Chapter 8 did not provide evidence on the relative accuracy of *ex ante* long-term forecasts from the models used to generate the IPCC's forecasts of climate change. It would have been feasible to assess the accuracy of alternative forecasting methods for medium- to long-term forecasts by using "successive updating." This involves withholding data on a number of years, then providing forecasts for one-year ahead, then two-years ahead, and so on up to, say, 20 years. The actual years could be disguised during these validation procedures. Furthermore, the years could be reversed (without telling the forecasters) to assess back-casting accuracy. If, as is suggested by forecasting principles, the models were unable to improve on the accuracy of forecasts from the naïve method in such tests, there would be no reason to suppose that accuracy would improve for longer forecasts. "Evaluating forecasting methods" in Armstrong 2001 provides evidence on this principle.

SUMMARY OF AUDIT FINDINGS

Our ratings of the processes used to generate the forecasts presented in the IPCC report are provided on the Public Policy Forecasting Special Interest Group Page at forecastingprinciples.com. These ratings have been posted since the time that our paper was presented at the International Symposium on Forecasting in New York in late June 2007.

Prior to the publication of this paper, we invited other researchers, using messages to email lists and web sites, to replicate our audit by providing their own ratings. In addition, we asked for information about any relevant principles that have not been included in the Forecasting Audit. At the time of writing, we have received neither alternative ratings nor evidence for additional relevant principles.

The many violations provide further evidence that the IPCC authors were unaware of evidence-based principles for forecasting. If they were aware of them, it would have been incumbent on them to present evidence to justify their departures from the principles. They did not do so. We conclude that because the forecasting processes examined in Chapter 8 overlook scientific evidence on forecasting, the IPCC forecasts of climate change are not scientific.

We invite others to provide evidence-based audits of what they believe to be scientific forecasts relevant to climate change. These can be posted on web sites to ensure that readers have access to the audits. As with peer review, we will require all relevant information on the people who conduct the audits prior to posting the audits on publicpolicyforecasting.com.

Climate change forecasters and their clients should use the Forecasting Audit early and often. Doing so would help to ensure that they are using appropriate forecasting procedures. Outside evaluators should also be encouraged to conduct audits. The audit reports should be made available to both the sponsors of the study and the public by posting on an open web site such as publicpolicyforecasting.com.

CLIMATE FORECASTERS' USE OF THE SCIENTIFIC LITERATURE ON FORECASTING METHODS

Bryson (1993) wrote that while it is obvious that when a statement is made about what climate will result from a doubling CO_2 it is a forecast, "I have not yet heard, at any of the many environmental congresses and symposia that I have attended, a discussion of forecasting methodology applicable to the environment" (p. 791).

We looked for evidence that climate modelers relied on scientific studies on the proper use of forecasting methods. In one approach, in April and June 2007, we used the Advanced Search function of Google Scholar to get a general sense of the extent to which climate forecasters refer to scientific studies on forecasting. When we searched for "global warming" and "forecasting principles," we found no relevant sites. Nor did we find any relevant citations of "forecastingprinciples.com" and "global warming." Nor were there any relevant citations of the relevant-sounding paper, "Forecasting for Environmental Decision-Making" (Armstrong 1999) published in a book with a relevant title: *Tools to Aid Environmental Decision Making*. A search for "global warming" and the best selling textbook on forecasting methods (Makridakis et al. 1998) revealed two citations, neither related to the prediction of global mean temperatures. Finally, there were no citations of research on causal models (e.g., Allen and Fildes 2001).

Using the titles of the papers, we independently examined the references in Chapter 8 of the IPCC Report. The Chapter contained 788 references. Of these, none had any apparent relationship to forecasting methodology. Our examination was not difficult as most papers had titles such as, "Using stable water isotopes to evaluate basin-scale simulations of surface water budgets," and, "Oceanic isopycnal mixing by coordinate rotation."

Finally, we examined the 23 papers that we were referred to by our survey respondents. These included Chapter 10 of the IPCC Report (Meehl et al. 2007). One respondent provided references to eight papers all by the same author (Abdussamatov). We obtained copies of three of those papers and abstracts of three others and found no evidence that the author had referred to forecasting research. Nor did any of the remaining 15 papers include any references to research on forecasting.

We also examined the 535 references in Chapter 9. Of these, 17 had titles that suggested the article might be concerned at least in part with forecasting methods. When we inspected the 17 articles, we found that none of them referred to the scientific literature on forecasting methods.

It is difficult to understand how scientific forecasting could be conducted without reference to the research literature on how to make forecasts. One would expect to see empirical justification for the forecasting methods that were used. We concluded that climate forecasts are informed by the modelers' experience and by their models—but that they are unaided by the application of forecasting principles.

CONCLUSIONS

To provide forecasts of climate change that are useful for policy-making, one would need to prepare forecasts of (1) temperature changes, (2) the effects of any temperature changes, and (3) the effects of feasible proposed policy changes. To justify policy changes based on climate change, policy makers need scientific forecasts for all three forecasting problems. If governments implement policy changes without such justification, they are likely to cause harm.

We have shown that failure occurs with the first forecasting problem: predicting temperature over the long term. Specifically, we have been unable to find a scientific forecast to support the currently widespread belief in "global warming." Climate is complex and there is much uncertainty about causal relationships and data. Prior research on forecasting suggests that in such situations a naïve (no change) forecast would be superior to current predictions. Note that recommending the naïve forecast does not mean that we believe that climate will not change. It means that we are not convinced that current knowledge about climate is sufficient to make useful long-term forecasts about climate. Policy proposals should be assessed on that basis.

Based on our literature searches, those forecasting long-term climate change have no apparent knowledge of evidence-based forecasting methods, so we expect that similar conclusions would apply to the other two necessary parts of the forecasting problem.

Many policies have been proposed in association with claims of global warming. It is not our purpose in this paper to comment on specific policy proposals, but it should be noted that policies may be valid regardless of future climate changes. To assess this, it would be necessary to directly forecast costs and benefits assuming that climate does not change or, even better, to forecasts costs and benefits under a range of possible future climates.

Public policy makers owe it to the people who would be affected by their policies to base them on scientific forecasts. Advocates of policy changes have a similar obligation. We hope that in the future, climate scientists with diverse views will embrace forecasting principles and will collaborate with forecasting experts in order to provide policy makers with scientific forecasts of climate.

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APPENDIX A: PEOPLE TO WHOM WE SENT OUR QUESTIONNAIRE

(* indicates a relevant response)

IPCC Working Group 1

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Union of Concerned Scientists

Brenda Ekwurzel, Peter Frumhoff, Amy Lynd Luers

Channel 4 "The Great Global Warming Swindle" documentary (2007)
Bert Bolin, Piers Corbyn*, Eigil Friis-Christensen, James Shitwaki, Frederick Singer, Carl Wunsch*

Wikipedia's list of global warming "skeptics"
Khabibullo Ismailovich Abdusamatov*, Syun-Ichi Akasofu*, Sallie Baliunas, Tim Ball, Robert Balling*, Fred Barnes, Joe Barton, Joe Bastardi, David Bellamy, Tom Bethell, Robert Bidinotto, Roy Blunt, Sonja Boehmer, Andrew Bolt, John Brignell*, Nigel Calder, Ian Castles*, George Chilingarian, John Christy*, Ian Clark, Philip Cooney, Robert Davis, David Deming*, David Douglass, Lester Hogan, Craig Idso, Keith Idso, Sherwood Idso, Zbigniew Jaworowski, Wibjorn Karlen, William Kininmonth, Nigel Lawson, Douglas Leahey, David Legates, Richard Lindzen*, Ross Mckitrick*, Patrick Michaels, Lubos Motl*, Kary Mullis, Tad Murty, Tim Patterson, Benny Peiser*, Ian Plimer, Arthur Robinson, Frederick Seitz, Nir Shaviv, Fred Smith, Willie Soon, Thomas Sowell, Roy Spencer, Philip Stott, Hendrik Tennekes, Jan Veizer, Peter Walsh, Edward Wegman

Other sources
Daniel Abbasi, Augie Auer, Bert Bolin, Jonathan Boston, Daniel Botkin*, Reid Bryson, Robert Carter*, Ralph Chapman, Al Gore, Kirtland C. Griffin*, David Henderson, Christopher Landsea*, Bjorn Lomborg, Tim Osborn, Roger Pielke*, Henrik Saxe, Thomas Schelling*, Matthew Sobel, Nicholas Stern*, Brian Valentine*, Carl Wunsch*, Antonio Zichichi.

Senator BOXER. Thank you very much.

And now, last but not least, by any means, is Andrew Wetzler, Director, Endangered Species Project for the Natural Resources Defense Council. Welcome, sir.

STATEMENT OF ANDREW E. WETZLER, DIRECTOR, ENDANGERED SPECIES PROJECT, NATURAL RESOURCES DEFENSE COUNCIL

Mr. WETZLER. Thank you for having me, Madam Chairman, thank you, members of the Committee.

You have my written statement, and rather than reiterating it now, I thought that I could just briefly respond to three of the points that we have heard in testimony from panelists, and I think questions from the Senators throughout the day.

The first is with regard to the role of modeling. Now, modeling is obviously a very important part of the Fish and Wildlife Service's conclusion that polar bears are threatened with extinction because of global warming. But it is not by any means the only basis. In fact, there are two separate, empirical, peer-reviewed bases for coming to that conclusion.

First are literally dozens of published papers observing behavioral and population changes in polar bear populations around the world. These include population declines, increased pup and young polar bear mortality, starvation in some populations, male polar bears turning to cannibalism in some populations, an increase in spike in drownings during storm events, and alterations in essential polar bear behavior, such as the location of maternal dens.

Now, all of those empirical observations are completely consistent with and indeed, are predicted by the decline of sea ice caused by global warming.

Second, a lot of the declining sea ice, as has been pointed out, and as is illustrated by the exhibit showing the decline of sea ice from 1980 to 2007, is in fact empirical. Those pictures are not forecasts, they are not models. That is observed sea ice loss. That is a sea ice loss that represents a million square miles of polar bear habitat. That is six Californias.

The second point I wanted to make very briefly was to respond to some of the testimony that we have heard about the Marine Mammal Protection Act. Now, there is no doubt that the Marine Mammal Protection Act is an important, landmark law in protecting marine mammals around the world. But the suggestion that the Endangered Species Act does not provide any additional or special protections for the polar bear if the polar bear was to be listed I think is just false.

And just very briefly, there is no equivalent of the Section 7 consultation procedure that we have heard so much about today in the Marine Mammal Protection Act. There is no requirement in the Marine Mammal Protection Act to protect habitat essential to the conservation of the species. That is an explicit requirement under the Critical Habitat Provisions of the Endangered Species Act. And there is no requirement in the Marine Mammal Protection Act which is present in the Endangered Species Act to prepare a recovery plan for a species, which would be a very important part of saving the polar bear in the long term, as the obligation under the Endangered Species Act to prepare a recovery plan for the polar bear.

Finally, I just wanted to briefly address, I think, the coincidence and timing between the delay that the U.S. Fish and Wildlife Service took, the extra legal delay, and the proposed lease sale that is going to go forward in the Chukchi Sea on February 6th. Senator Boxer, I think that you were right to point out that this has raised suspicions in many people's minds. I think given the history of this Administration, those suspicions are well-founded.

But even if we want to give Director Hall the benefit of the doubt, and the Fish and Wildlife Service, and assume that the delay was simply caused by bureaucratic reasons, I think it is essential to recognize that there is absolutely no reason on the other side of the equation, on the Minerals Management Service side of the equation, to move ahead with this lease sale now. There is nothing preventing the Secretary of the Interior form simply reopening the decision to proceed with the lease sale and hold it in abeyance until the Fish and Wildlife Service makes a considered decision about whether or not to list the polar bear. At a minimum, I would urge the Administration to take that very common sense step, which I think would defuse a lot of these suspicions.

Thank you.

[The prepared statement of Mr. Wetzler follows:]

NRDC
THE EARTH'S BEST DEFENSE

NATURAL RESOURCES DEFENSE COUNCIL

Statement of

Andrew E. Wetzler

Director, Endangered Species Project

Natural Resources Defense Council

Before the

Committee on Environment and Public Works

United States Senate

January 30, 2008

Introduction

Good morning Madam Chairman and Members of the Committee. My name is Andrew Wetzler and I am the Director of the Endangered Species Project for the Natural Resources Defense Council (NRDC). NRDC is a not-for-profit environmental advocacy organization with over 1 million members and activists served from offices in New York, Washington, D.C., Los Angeles, San Francisco, Chicago, and Beijing. NRDC's mission is to safeguard the Earth: its people, its plants and animals, and the natural systems on which all life depends. I thank the Committee for inviting me to testify today about threats and protections for the polar bear, one of the world's most spectacular and well-recognized animals.

Sadly, today polar bears stand on the brink of extinction. Threatened by a combination of factors ranging from toxic contamination to oil and gas pollution but, most importantly, global warming, polar bears are seeing the sea ice habitat on which they depend disappear at an alarming rate. There is now overwhelming scientific agreement that sea ice loss in the Arctic threatens polar bears with extinction. The International Union for the Conservation of Nature's Polar Bear Specialist Group has officially categorized the polar bear as a "vulnerable" species, defined as a species "facing a high risk of extinction in the wild."[1] Based on the "best scientific and commercial data available," the United States Fish and Wildlife Service has proposed classifying the polar bear as a threatened species under the federal Endangered Species Act, 16 U.S.C. §§ 1531, *et seq.*, and, after an extensive review, the United States Geological Survey has concluded

[1] IUCN (2001).

that two-thirds of the worlds polar bears, including all polar bears in Alaska, are likely to be extirpated by 2050.[2]

As grim as the situation facing polar bears is, it is not hopeless. Prompt action now to increase protection for polar bears throughout their range, combined with concerted action by Congress to control and reduce greenhouse gas emissions is needed if polar bears are to survive. Indeed, the best available science clearly indicates that future sea ice extent could be significantly affected by reductions in the emission of global warming pollution.[3] By stabilizing and gradually reducing carbon dioxide concentrations and significantly reducing concentrations of shorter-lived greenhouse gases, it should be possible to stabilize arctic sea ice extent and eventually allow for it to recover. While the situation confronting polar bears is critical, it is not too late if we act now.

It is thus particularly disturbing that the Fish and Wildlife Service has repeatedly delayed making a final decision about whether to protect polar bears under the Endangered Species Act. A formal petition to protect the polar bear was filed under the Endangered Species Act in February, 2005. Yet, despite the Endangered Species Act's clear requirement that the Fish and Wildlife Service make a final determination about the polar bear's status no later than two years after such a petition is filed, 16 U.S.C. § 1533(b), almost three years later the polar bear is still not protected. In January, the Fish and Wildlife Service announced that it would delay making a

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[2] Amstrup et al. (2007).
[3] Durner et al. (2007).

final decision about whether to protect the polar bear for at least another month.[4] This announcement came on the heels of the U.S. Mineral Management Service's plans to lease 46,000 square miles of key polar bear habitat in the Chukchi Sea for oil and gas development, home to between 1,500 and 2,000 bears, on February 6, 2008.[5]

Global Warming Threatens the Polar Bear With Extinction

The Endangered Species Act requires that decisions to list a species as either "endangered" or "threatened" be made "solely on the basis of the best scientific and commercial data available." 16 U.S.C. § 1533(b)(1)(A). Even a cursory review of the available scientific literature leaves little doubt that polar bears are threatened by global warming.

Polar bears (*Ursus maritimus*) are pagophilic ("ice-loving") mammals whose preferred habitat is the annual sea ice over the continental shelf and inter-island archipelagoes of the Arctic basin. Polar bears are almost completely dependent on sea-ice for hunting and migrating, and also rely on sea-ice to find mates and, in some populations, to provide dens for pregnant females.[6] The current global population of polar bears is estimated to be between 20,000 and 25,000 individuals, divided into 19 sub-populations, all of which are located in the Arctic. Polar bear populations are not found outside of areas that have significant sea ice coverage for much of the year.

The greatest threat to polar bears is the effect of warming and sea ice declines on the availability

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[4] Statement for Polar Bear Decision (January 7, 2008) (available at: http://www.fws.gov/news/NewsReleases/showNews.cfm?newsId=54D2A6BD-E928-94E6-6BA905F3F540B8F7)
[5] Lunn et al. (2002).
[6] Regehr et al. (2007); Derocher et al. (2004).

and abundance of polar bear's main prey, ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*).[7] These seal species use sea-ice as resting places, haul-out sites, feeding grounds and habitat to raise their cubs. Changes in sea-ice will likely impact the availability and abundance of seals as prey for polar bears thereby reducing polar bear fat stores, resulting in longer fasting periods and decreasing successful reproductive rates. As three of the world's leading polar bear authorities concluded in 2004, when assessing the potential impact of widespread changes in sea ice on the polar bear: "anything that significantly changes the distribution, abundance, or even the existence of sea ice will have profound effects on polar bears."[8]

Based on ten climate models that have done the best job of simulating current ice conditions and are thus expected to do the best job of simulating future ice conditions, and using the Intergovernmental Panel on Climate Change ("IPCC") A1B "business as usual" scenario of future emissions, the U.S. Geological Survey (USGS) recently evaluated the future range-wide status of the polar bear.[9]

The USGS divided the range of the polar bear into four "ecoregions" based on major differences in current and projected sea ice conditions. (See Figure 1, below.) These ecoregions, which include all 19 polar bear subpopulations, are as follows:

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[7] Derocher et al. (2004); Ferguson, et al (2005).
[8] Derocher, et al. (2004), p. 164.
[9] Amstrup, et al. (2007). In the A1B scenario, atmospheric carbon dioxide concentrations reach 717 parts per million by 2100.

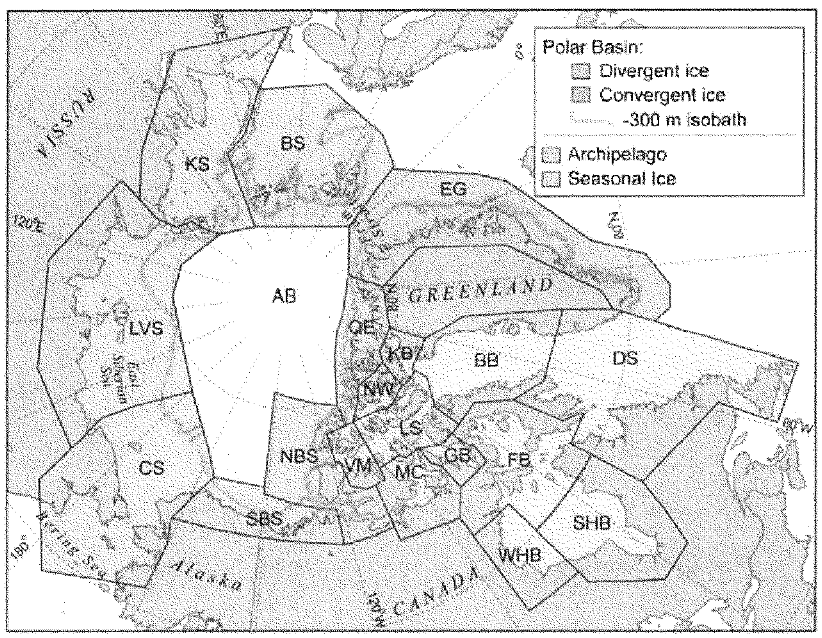
- *Seasonal Ice Ecoregion*, which includes Hudson Bay, and occurs mainly at the southern extreme of the polar bear range;

- *Archipelagic Ecoregion* of the Canadian Arctic;

- *Polar Basin Divergent Ecoregion*, where ice is formed and then drawn away from near-shore areas, especially during the summer minimum ice season; and

- *Polar Basin Convergent Ecoregion*, where sea ice formed elsewhere tends to collect against the shore.

Figure 1--Polar Bear Habitat Ecoregions
(*Source*: Amstrup et al. (2007), Figure 1)



Based on this modeling, USGS concluded that polar bears will completely disappear from the Seasonal and Divergent Ice Ecoregions by the middle of this century. Polar bears may survive in the Archipelago Ecoregion and portions of the Convergent Ice Ecoregion through the end of this century, however, even in these regions, the probability of extinction by century's end is still extremely high: over 40% in the Archipelago Ecoregion and over 70% in the Convergent Ice Ecoregion, under any of the sea ice projections. Table 1, below, expresses the most likely outcome for polar bear populations in each region in a forty-five and one hundred year time-frame.

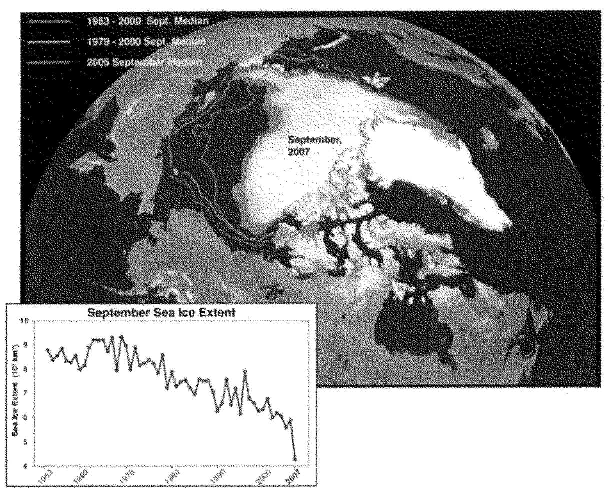
Table 1--Most Likely Modeled Outcome of the Four Polar Bear Ecoregions
(*Source*: Amstrup et al. (2007) (Table 8)).

Ecoregion	Time Period	Most Likely Outcome	Probability of Extinction
Seasonal Ice	Year 45	EXTINCT	77.19%
	Year 100	EXTINCT	88.15%
Divergent Ice	Year 45	EXTINCT	80.33%
	Year 100	EXTINCT	83.89%
Convergent Ice	Year 45	EXTINCT	35.06%
	Year 100	EXTINCT	77.30%
Archipelago	Year 45	SMALLER	10.56%
	Year 100	EXTINCT	41.07%

When assessing these predictions it is extremely important to bear in mind that the USGS's projections must be viewed as conservative, as the actual *observed rate of sea ice loss has* *exceeded these models predictions*. This is noted throughout the USGS report (*e.g.* Amstrup et al. (2007), pp. 34, 36).

Indeed, as shown in Figure 2, after the USGS report was released, scientists reported that a new record summer sea ice minimum had been reached in 2007. The new reported record low of 1.59 million square miles is far less than the previous record low of 2.05 million square miles and 50% lower than conditions in the 1950s to the 1970s.[10] The 2007 record low is also 1 million square miles—an area approximately six times the size of California—less than the long-term average minimum of 2.60 million square miles.[11]

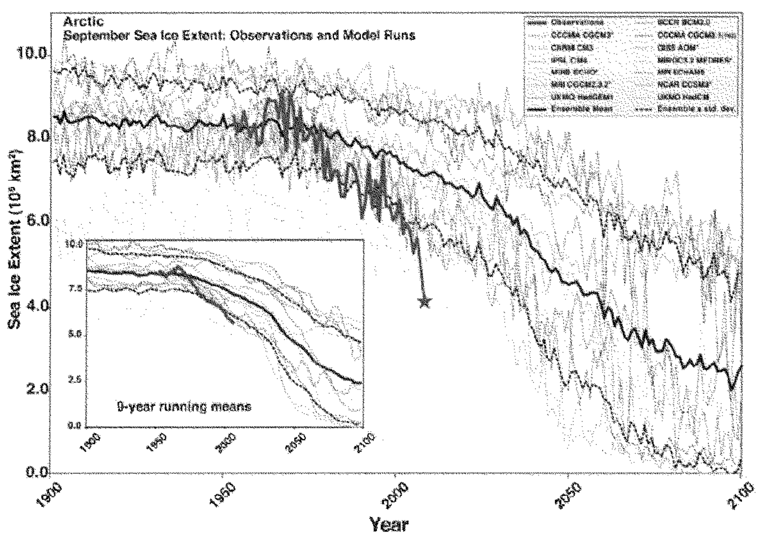
Figure 2--Sea ice concentration for September 2007, along with median extent from1953 to 2000 (red curve), from 1979 to 2000 (orange curve), and for September 2005 (green curve). September ice extent time series from 1953 to 2007 is shown at the bottom.
(*Source*: Stroeve et al. (2008) (Figure 1)).



[10] NSIDC 2007a,b; Stroeve et al. (2008).
[11] NSIDC 2007a,b.

This record low is far below that predicted by any of the ten climate models used by the USGS. Moreover, as illustrated by Figure 3, below, the 2007 minimum sea ice extent is below that predicted by the ensemble mean of the Stroeve et al. (2007) models for 2050. In other words, *there was less ice in the Arctic in 2007 than over half of the climate models predicted for 2050.*[12] Leading sea ice researchers now believe that the Arctic could be completely ice free in the summer as early as 2030.[13]

Figure 3--Actual Observed Sea Ice Extent (in Red) Compared to Model Projections
(*Source*: After DeWeaver (2007); Stroeve et al. 2007.)



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[12] It is also worth noting that the carbon dioxide concentrations cited for these scenarios in 2100 are just the level projected to be attained in that year, not the level at which CO2 concentrations would be stabilized. Indeed, under all of these scenarios CO2 concentrations would continue to rise indefinitely after 2100.

[13] Stroeve et al. (2008).

The effects of the decline of sea ice can already be seen in many polar bear populations around the world, and are particularly pronounced in the Western Hudson Bay, the polar bear's southern-most population.

Over the past two decades the condition of adult polar bears in the Hudson Bay has deteriorated and this has been reflected in the reproductive cycle of females and in total population levels. In 1987 there were 1,194 polar bears in the Western Hudson Bay. In 2004 only 935 were recorded, a drop of 22%.[14] This decline is reflective of reduced breeding success and lower survival of senescent-adult polar bears (less than 20 years in age) and can be attributed to a combination of overharvest and "increased natural mortality associated with earlier sea ice breakup."[15] Scientists now predict that "more northerly polar bear populations will experience declines in demographic parameters similar to those observed in western Hudson Bay" in light of the "long term and severe" forecasts of ice break up in the Arctic.[16]

And, in fact, the Western Hudson Bay population is not the only one that is already suffering from the effects of climate change. The Southern Beaufort Sea population is now also classified by the Polar Bear Specialist Group as declining.[17] In addition to an overall population decline, the Southern Beaufort Sea population has experienced statistically significant declines in cub survival, cub skull size, and adult male weight and skull size—the same types of declines observed in Western Hudson Bay prior to the decline of that population.[18] Other signs of poor

[14] Aars et al. (2006).
[15] Regehr et al. (2007), p. 2681.
[16] *Id.*, p. 2681.
[17] Aars et al. (2006).
[18] Regehr et al. (2007).

nutrition have been recorded in the Southern Beaufort Sea, where multiple female polar bears and their young have starved to death.[19]

There are also indications that adult male polar bears may be turning to cannibalism as a means to supplement their diet. Amstrup (2006) reports three instances of intraspecific predation and cannibalism of polar bears in the Beaufort Sea, including the unprecedented killing of a parturient female in her maternal den. The authors hypothesize that these killings—which are the first reported in 24 years of research on polar bears in the southern Beaufort Sea and 34 years in northwestern Canada—may be caused by nutritional stress due to longer ice-free seasons. A similar incident was recently reported among polar bears on Phippsøya, in Norway's Svalbard Islands.[20]

The retreat of sea ice may also result in significant behavior changes in polar bears, some of which put bears at increased risk of mortality. Most female polar bears, for example, exhibit a preference for den locations that are on land. As sea-ice extent declines, and hence the sea-ice edge moves northwards, polar bears will have to travel greater distances, and expend more energy, to reach their preferred den areas or they will have to change den locations. Sometimes this can have catastrophic consequences. For example, in Alaska's Southern Beaufort Sea, survey results reported by the Minerals Management Service reveal that in September 2004 at least four polar bears, and up to twenty-seven, drowned off the north coast of Alaska where the sea-ice retreated a record 160 miles from the coast.[21] As an alternative to traveling long

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[19] Regehr et al. (2006).
[20] Stone and Derocher (2007).
[21] Monnett et al. (2005).

distances, some female polar bears may choose to leave the ice at break-up and summer in the location of their den. Although this avoids additional energy expended during travel, it will instead require an additional fasting period because females will leave the sea-ice feeding grounds earlier than preferred, possibly resulting in fasting of up to eight months.[22]

Some polar bear populations also den in snow and changes in the proportion of precipitation falling as snow compared to rain will affect such denning behavior. The Arctic Council and the International Arctic Science Committee reports that den collapses due to increased frequency and intensity of spring rains has already occurred in some cases, resulting in the death of some females and their cubs.[23] In addition to an increase in unseasonable rains, global warming is expected to increase the frequency, extent, and season for fires in Arctic regions which, in turn, may significantly reduce availability of suitable denning habitat on land.[24]

In short, global warming thus poses an immediate, accelerating, and mortal threat to polar bear populations around the world.

Other threats to polar bears

As polar bear populations continue to be affected by the loss, retreat, and earlier break up of sea ice, it is extremely important to minimize other stresses on the population. In particular continued and expanded oil and gas exploration and development, toxic contamination and, in

[22] Derocher et al. (2004).
[23] ACIA (2004).
[24] Richardson (2007).

some populations, over-harvesting are all additional sources of disruption, injury, and mortality to polar bears. Some of these threats are expected to be exacerbated by global warming.

Oil and Gas Exploration

Oil and gas exploration can have a significant effect on polar bear populations. Oil and gas activities can alter important onshore and offshore polar bear habitat and is often accompanied by air traffic, vessel traffic and other supporting infrastructure. A large oil spill could have catastrophic consequences for polar bear populations. In addition, anthropogenic noise pollution, generated by seismic exploration and oil and gas development activities, may also have a negative effect on polar bears. Denning polar bears, for example, are likely to be susceptible to disturbance from activities related to oil and gas exploration and development. Noise disturbance from seismic activities of oil exploration as well as ground and air transportation can be heard within 300 meters of dens.[25] A recent study of auditory evoked potentials found that polar bears hear acutely across an unexpectedly wide frequency range and, on this basis, the authors expressed caution over the introduction of noise into their environment.[26] Exposure to noise from drilling and vehicles may cause bears to abandon their dens.[27] In other circumstances, den disturbance has been linked to lower birth weight in female cubs.[28]

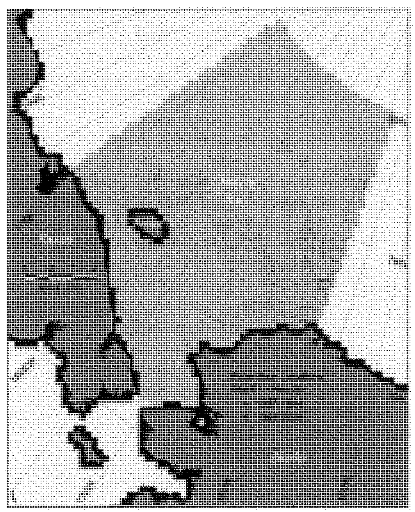
Of particular concern is pending Lease Sale 193 in the Chukchi Sea. Polar bears in the Chukchi Sea are thought to number between 1,500 and 2,000 individuals (although much about the population still remains uncertain). Lease Sale 193 would open up 46,000 square miles of polar

[25] Blix and Lentfer (1992).
[26] Nacthingall (2007).
[27] Amstrup (1993); Linnell et al. (2000).
[28] Lunn et al. (2004).

bear habitat in the Chukchi Sea to oil and gas development. As can be seen from Figure 4 and Figure 5, below, polar bears are widely distributed throughout the Chukchi Sea, as are polar bear denning sites.[29]

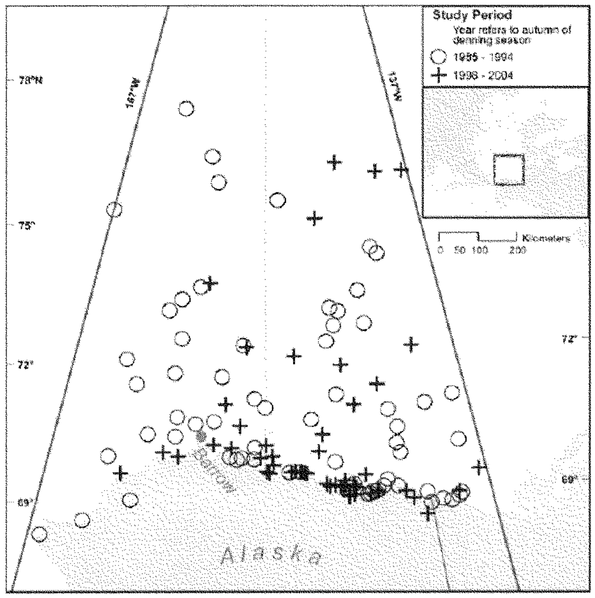
Figure 4--Chuckchi Sea polar bear distribution
(*Source*: Durner et al (2007))

Figure 1. Boundary of the full Chukchi Sea study area (intermediate gray) as defined by a 25 km x 25 km rasterized polygon that encompassed offshore (>25 km) waters between 170°E–156°W and 66°N–80°N. Dot symbols denote all polar bear satellite relocations within 170°E–156°W and 66°N–80°N that were collected during the autumn months (September–November), mostly from an early-vintage field study (1987–1994) of the Chukchi Sea bear population (red), and exclusively from a recent-vintage field study (1997–2005) of the Beaufort Sea bear population (blue).



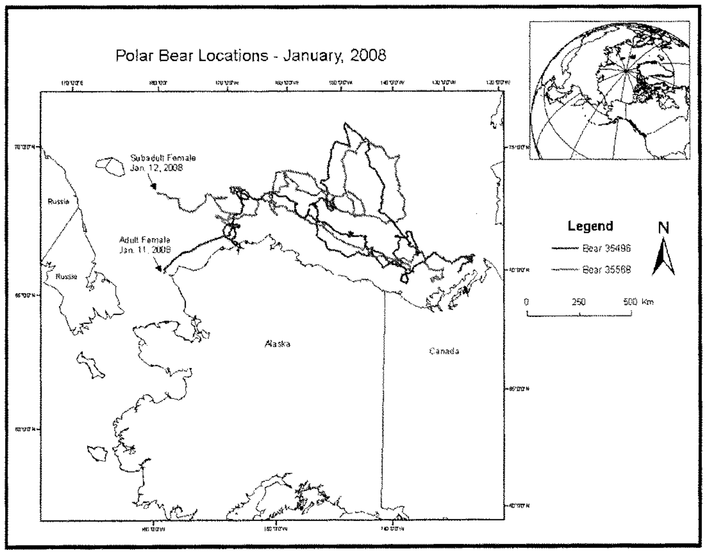
[29] Fischbach et al. (2007).

Figure 5--Distribution of polar bear den entrance locations
(*Source*: Fischbach et al. (2007))



As illustrated in Figure 5, there has been an apparent shift in denning locations in response to changing sea ice stability and the lengthening of the Arctic melt season. Significantly, researchers are also beginning to observe large scale polar bear movements, including the movement of bears from the Canadian portion of the Southern Beaufort Sea population into the Chukchi Sea (see Figure 6, below). As conditions in the Southern Beaufort Sea decline, the Chukchi Sea's habitat may become increasingly important.

Figure 6--Selected Locations of Bears 35496 and 35568 through 12 January 2008
(*Source*: Andrew Derocher, unpubl. data.)



In addition to the risks that accompany any oil development, Lease Sale 193 also poses an unacceptable risk of a large oil spill. The Mineral Management Service's Final Environmental Impact Statement for Chukchi Sea Planning Area Oil and Gas Lease Sale 193 and Seismic Surveying Activities (FEIS) estimates that there is at least a 40%, and as much as a 54%, chance of a large spill if the sale areas are developed.[30] Bears who come in contact with oil generally attempt to clean themselves, ingesting the oil, which can be fatal.

[30] Minerals Management Service (2007), p. IV-2; Table A.1-27.

Toxic Contamination

In addition to threats from global warming and oil and gas development, the polar bear, as one of the Arctic's apex predators, is particularly vulnerable to biocontamination from a range of substances, including persistent organic pollutants (or "POPs") and heavy metals. Its vulnerability is exacerbated by certain aspects of its biology, such as its long annual fast, which tends to elevate its toxicity levels at a time when the animal is under greatest stress. Moreover, global warming stands to create new pathways for concentration of pollutants in the region, with the remobilization of toxics from melting permafrost and the rise of industrial activity as the climate warms.

In general, pollutant levels in the Arctic remain high and in some cases are increasing. Sampling taken from 1996 to 2002 indicates that regional concentrations of certain chlorinated hydrocarbon contaminants (CHCs) did not decline as might have been expected in response to reduced production.[31] Based on their CHC loads, the East Greenland and Svalbard polar bear populations are at greatest risk of health effects.[32] Perfluorochemicals (PFOS), whose world-wide circulation was only recently discovered, are considered important contaminants in Greenland, with biomagnification of PFOS observed in the polar bear populations there and in South Hudson Bay.[33] Some perfluorochemicals are reported to have rapidly increased in the Canadian Arctic as well[34] and have been found in significant concentrations in polar bears of the Beaufort and Chukchi Seas, though at lower levels than in North Atlantic populations.[35]

[31] Verreault et al. (2005a)
[32] *Id.*
[33] Bossi et al. (2005), Smithwick et al. (2005).
[34] Braune et al. (2005); see also Prevedouros et al. (2005).
[35] Kannan et al. (2005), Smithwick et al. (2005).

Concentrations of Polybrominated diphenyl ethers (PBDEs) have for the first time been reported in Alaskan bears.[36] In addition, according to the Arctic Monitoring and Assessment Programme ("AMAP"), the region as a whole remains highly vulnerable to the effects of radionuclides.[37]

Several recent studies provide further indication of the health impacts of contaminants. Some congeners have been shown to significantly affect lymphocyte production in polar bears, leaving the animals susceptible to infection.[38] On the basis of that study and others, a number of Canadian and Norwegian researchers have concluded that organochlorines could already be having population-level impacts on the species.[39] A separate study on East Greenlandic polar bears correlated liver inflammation with long-term exposure to organohalogens, such as PBDEs, which have also been linked to renal lesions.[40]

Additional research that has emerged, particularly on brominated flame retardants like PBDEs, which are rising in the Arctic due to long-range transport from western Europe, eastern North America, and other industrial regions.[41] Studies have demonstrated slow biodegradation[42] and high biomagnification[43] of certain PBDEs in a number of polar bear subpopulations, and a study of the food web in the Norwegian Arctic indicates that some congeners already exceed detection thresholds even in zooplankton and biomagnify specifically through the trophic system.[44] PBDEs and other organohalogens were shown to adversely affect the male and female genitalia

[36] Kannan et al. (2005).
[37] AMAP (2004).
[38] Lie et al. (2004); see also AMAP (2005).
[39] Fisk et al. (2005).
[40] Sonne et al. (2005).
[41] de Wit et al. (2006).
[42] Dietz et al. (2007).
[43] Muir et al. (2006).
[44] Sørmo et al. (2006).

of East Greenland polar bears, reducing their size and robustness and potentially compromising reproduction in these animals.[45] The past year also saw further evidence on the health impacts of other contaminants. Organochlorines, for example, were found to alter hormone production in both male and female polar bears; modeling indicates that even low levels of chronic exposure to these chemicals can impair the reproduction and immune system function of their offspring.[46]

Of particular note is the possible increase in global mercury deposition, despite emission reductions adopted in the 1980s by North America and Europe.[47] Rising concentrations in the Northwest Atlantic and other parts of the Arctic have been attributed to long-range transport from Asia, which now accounts for roughly half of the world's mercury pollution.[48] Concentrations are substantially higher in the Canadian Arctic than elsewhere, and there is strong evidence that levels in Canadian polar bears have increased substantially since the beginning of the industrial age.[49] The higher levels that have been reported in the Canadian Arctic may be due, in part, to global warming.[50] Indeed, the increased precipitation that climate change is expected to bring is likely to make the Arctic a more effective trap for heavy metals.[51] While mercury concentrations have declined in East Greenlandic polar bears, consistent with emission reductions from European coal plants, levels remain about 11 times higher than the pre-industrial baseline.[52]

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[45] Sonne et al. (2006b).
[46] Ropstad et al. (2007).
[47] AMAP (2005).
[48] Dietz et al. (2006).
[49] Braune et al. (2005).
[50] Braune et al. (2005).
[51] Macdonald et al. (2005).
[52] Dietz et al. (2006).

I would note that this Committee is now considering important legislation, the Mercury Export Ban Act of 2007, which will help stem global mercury pollution, by banning the export of elemental mercury from the United States. Elemental mercury is still used in a number of commercial products and industrial processes worldwide. While the US has become increasingly vigilant about managing mercury within its borders, much of our mercury is sold on the global market, where it is used in highly polluting industries, mainly in developing countries. Because mercury is a global pollutant, mercury emitted in those countries can travel around the world, and end up in Arctic waters and fish and wildlife, including polar bears. By preventing the sale of United States mercury overseas, the Mercury Export Ban Act of 2007 will help limit the US contribution to the overall global mercury contaminant pool. I urge the committee to consider and pass this important legislation as quickly as possible.

Overharvest

While sports hunting of polar bears is currently prohibited in the United States, Russia, and Norway, some polar bear populations are subject to unsustainable harvest levels either as the result of poaching (as is the case in Russia) or hunting practices (as is the case in Greenland and some parts of Canada). Over-harvest of polar bears thus has a concentrated, but potentially severe, effect on several polar bear populations, some of which have already been classified as "declining" by the Polar Bear Specialist Group.[53]

Poaching of polar bears in the Russian Federation continues to be a serious problem. In 2002, for example, experts estimate that poachers took between 250 and 300 bears on the north coast of

[53] Aars et al. (2006).

Chukotka.[54] Poaching may be exacerbated by receding sea ice, which forces polar bears onto shore early. And more polar bear skins and other commercial products are being advertised on web sites than ever before.[55] However, the Agreement between the United States of America and the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population, which was recently ratified by the U.S. Senate, is an important tool whose implementation may help to alleviate illegal harvest of polar bears in Russia.

In Canada and Greenland, the levels of legal harvest of some polar bear populations are far too high and, in and of themselves, may threaten the continued existence of these populations. For example, despite the scientific evidence, discussed above, that the western Hudson Bay population is experiencing severe declines, the Fish and Wildlife Service has noted that, while this population has a maximum sustained yield of only 44 bears, Canada allows 62 bears to be removed from the western Hudson Bay.[56] A recent study also concluded that selective harvest of male polar bears by sports hunters could lead to a "sudden and rapid reproductive collapse" due to a combination of reduced population density and altered female-to-male ratios.[57] Moreover, receding sea ice, caused by global warming, may bring more polar bears in contact with people, increasing hunting opportunities and potentially leading to misperceptions of polar bear abundance.[58]

[54] Ovsiyanikov (2003).
[55] *Id.*
[56] 72 Fed. Reg. at 1084.
[57] Molnár et al (2008).
[58] Stirling and Parkinson (2006).

When discussing hunting, it is important to emphasize, however, *that protecting the polar bear under the Endangered Species Act will not affect subsistence harvest by native Alaskans.* Section 9(e) of the Endangered Species Act provides that the Act's prohibition against "taking" a listed species does not apply to Alaskan Natives (or non-native residents of Native villages) if such taking is primarily for subsistence purposes. 16 U.S.C. § 1539(e). The Act also exempts "authentic native article of crafts and clothing" produced from listed species. Id. Significantly, the Marine Mammal Protection Act, which *already* regulates native harvest of polar bears in Alaska, contains a nearly identical provision. See 16 U.S.C. § 1371(b) ("Exemptions for Alaskan natives").

Prompt Action is Needed to Save the Polar Bear

Congress Must Pass Legislation to Control Global Warming Pollution

The situation facing polar bears is undeniably grim. But it is not hopeless. The USGS Reports illustrate this very point. As discusses above, in its reports the USGS considered several scenarios developed by the IPCC in implementing its models. These scenarios indicate that arctic sea ice conditions during the coming century will be sensitive to future emission levels. Scientists have noted, for example, that the ensemble-mean summer minimum sea ice extent is reduced by 65% in the highest emission scenario considered (A2) and by 45.8% in the lowest scenario considered (B1), thus suggesting that reducing global warming emissions can substantially affect future reductions of sea ice in polar bear habitat.[59] In fact, the USGS reports themselves note that:

[59] DeWeaver (2007); Zhang and Walsh (2006).

> "Differences between the A1B and B1 scenarios (for the CCSM3 model) in timing and relative magnitude of projected sea ice extent are remarkably similar to the inverse of their imposed CO2 loadings…"[60]

The U.S. government as well as many other governments and independent researchers have developed climate mitigation scenarios that would stabilize greenhouse gas concentrations well below the levels considered in the scenarios used by the USGS reports. For example, the U.S. Climate Change Technology Program Strategic Plan (DOE/PI-0005, 2006: 35) considers a "Very High Constraint" scenario in which total radiative forcing from greenhouse gases is stabilized at less than 3.5 W/m2, corresponding to stabilizing CO2 concentrations at approximately 450 parts per million (ppm). The Union of Concerned Scientists recently reviewed scenarios designed to limit total global warming to no more than 2 degrees Celsius, concluding that this is feasible if the United States reduces its emissions by 4 percent per year starting in 2010, assuming other countries also take appropriate action.[61] Finally, Dr. James Hansen, Director of NASA's Goddard Institute for Space Studies, has proposed an "alternative" scenario aimed at keeping additional global warming well below 1 degree Celsius.[62] His recent review of current trends concludes that it is still possible to achieve this objective.[63] Thus, by stabilizing and gradually reducing CO2 concentrations while significantly reducing concentrations of shorter-lived greenhouse gases, it should be possible to stabilize arctic sea ice extent and eventually allow for it to recover. This observation is particularly important given the possibility that some polar bear refugia may continue to exist in the Arctic through the end of the century.

[60] Durner, et al (2007), p. 16. See also Holland et al. (2006) (finding that periods of rapid decline in arctic sea ice are less likely under the B1 scenario than under the A1B or A2 scenarios).
[61] Luers et al. (2007).
[62] Hansen, et al (2000).
[63] Hansen and Sato (2007).

In order to accomplish this goal, it is crucial for Congress to enact comprehensive legislation to reduce global warming pollution. The Lieberman-Warner Climate Security Act of 2008 is one of the strongest global warming bills currently being considered by Congress and I would like to thank Senator Boxer and other members of the Committee for their leadership in both strengthening and moving this bill through the Committee last year. NRDC urges you to move the Lieberman-Warner bill to the Senate floor as soon as possible and we stand ready to assist you to help further strengthen the bill. NRDC will also work to prevent any amendments from passing that would weaken the emission limits, which will make it much more challenging to stablalize atmospheric concentrations of C02 at a level that is sufficient to save the polar bear and the thousands of other species that are threatened by global warming.

<u>Protecting the Polar Bear Under the Endangered Species Act Will Help Save the Species</u>

Protecting the polar bear under the Endangered Species Act will also provide crucial long and short-term protections to the species. Listing the polar bear under the Endangered Species Act will have the following immediate benefits.

First, once a species is listed as threatened or endangered, federal agencies must ensure, through a process known a "consultations" with the Fish and Wildlife Service, that any action they authorize, fund, or carry out will not "jeopardize the continued existence" of the species or "result in the destruction or adverse modification" of that habitat. 16 U.S.C. § 1536(a)(2). While the Section 7(a)(2) duty not to "jeopardize the continued existence" of listed species helps to ensure their survival, the critical habitat duty allows these species to recover so that they may eventually be delisted.[64]

The consultation process, which can be informal or formal in nature, almost never stops projects from going forward.[65] That is because the Fish and Wildlife Service is required to provide federal agencies with a list of "reasonable and prudent measures" that can be implemented to reduce the impact of proposed federal actions and allow the action to proceed. 16 U.S.C. § 1536(b)(4). Thus, in practice, the consultation process will provide an important safety net for polar bears, by requiring federal agencies to implement additional safeguards to the species, while allowing them to go forward. Significantly, this consultation requirement will apply to many of the threats facing polar bears, from toxic pollution, to oil and gas development, and, most importantly, sources of global warming pollution that require a federal permit.

Second, the Fish and Wildlife Service will be required to designate "critical habitat" for the polar bear. 16 U.S.C. § 1533(a)(3)(A)(i). Critical habitat is defined in Section 3 of the ESA as:

> (i) the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the [Endangered Species Act], on which are found those physical or biological features (I) essential to the conservation of the species and (II) that may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it was listed....upon a determination by the Secretary that such areas are essential for the conservation of the species."

[64] *See Gifford Pinchot Task Force v. U.S. Fish and Wildlife Serv.*, 378 F.3d 1059 (9th Cir. 2004); *Sierra Club v. U.S. Fish and Wildlife Serv.*, 245 F.3d 434 (5th Cir. 2001).

[65] According the Endangered Species Coaliton, a study by the Fish and Wildlife Service found that between 1987 and 1992 the consultation process only resulted in the cancellation of .05% of proposed federal actions. *See* Endangered Species Coalition, "ESA Agency Action Facts" (available at: http://www.stopextinction.org/site/c.epIQKXOBJsG/b.861809/k.C6E0/ESA__Agency_Actions.htm)

16 U.S.C. § 1532(5)(A). As discussed above, designating critical habitat will provide additional protections to essential polar bear habitat, including both onshore habitat used for maternal denning and sea ice habitat used for most of the bears' essential biological functions.

Third, protecting the polar bear under the Endangered Species Act will impose a prohibition against any individual "taking" of a polar bear without a permit. It should be noted, however, that, while the Endangered Species Act prohibits the "take" of a species listed as endangered, this same prohibition does not apply to threatened species, except by regulation. 16 U.S.C. § 1533(d). Thus, under certain circumstances, the Service may issue regulations under Section 4(d) of the ESA (these regulations are generally referred to as "special rules") that authorize activities that result in the take of threatened species that could not be authorized for endangered species. While NRDC believes that the scientific evidence now warrants an "endangered" rather than a "threatened" listing, it is important to note that if the Fish and Wildlife Service does list the polar bear as a threatened species, that designation will provide the agency with the ability to modify the Endangered Species Act's taking requirements for the species. Given this Administration's history of undercutting environmental protections, particularly when it comes to the energy industry, we would urge that any such regulations be subject to vigilant oversight by this Committee.

Fourth, protecting the polar bear under the Endangered Species Act will require the Fish and Wildlife Service to prepare a "recovery plan" for the polar bear. Recovery plans are required to include (1) "site specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species"; (2) "objective, measurable criteria" for determining a species to be recovered; and (3) "estimates of the time required" to carry out the recovery plan. 16 U.S.C. § 1533(f)(1)(B). Preparing a recovery plan for the polar bear will not only be of enormous benefit to the species, by forcing the Fish and Wildlife Service to precisely confront the various threats that it faces and put the species on the road to recovery, but it will also force the Bush Administration to deal directly and quantifiably with the climate change science in a way it has mostly resisted to date.

Finally, listing the polar bear under the Endangered Species Act will be a powerful acknowledgement of the toll that global warming is taking not just on polar bears, but on the entire Arctic ecosystem and, indeed, on wildlife around the world. Polar bears may be the first species listed under the Endangered Species Act principally because of global warming, but if we do not act soon to stabilize and reduce greenhouse gas emissions, they will be far from the last.

The Fish and Wildlife Service's History of Delays in Protecting Polar Bears

Given the overwhelming evidence that polar bears are facing extinction because of global warming, the need for prompt action to protect the polar bear, and the many benefits that Endangered Species Act protections would provide, it is particularly dismaying that the Fish and Wildlife Service has continually sought to delay making a final decision about whether to list polar bears.

The Endangered Species Act allows "any person" to petition the Secretary of the Interior or Secretary of Commerce to list a species as either "endangered" or "threatened." 16 U.S.C. §

1533(a). An "endangered species" is defined as any species "which is in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). A "threatened species" is defined as any species "which is likely to become an endangered species within the foreseeable future." 16 U.S.C. § 1532(20).

When making listing determinations, the Service must consider five statutory listing criteria: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (e) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence. 16 U.S.C. § 1533(a)(1). If a species meets the definition of threatened or endangered because it is imperiled by any one or more of these five factors, the Service must list the species. 16 U.S.C. § 1533(1). The Service must base all listing determinations "solely on the basis of the best scientific and commercial data available." Id. at § 1533(b)(1)(A).

On February 16, 2005, the Center for Biological Diversity petitioned the Fish and Wildlife Service to list the polar bear as a threatened species. The Petition was principally based on the threat that global warming poses to the polar bear's sea ice habitat, but also discussed ongoing threats from toxic contamination, oil and gas development, and overhunting. NRDC and Greenpeace USA formally joined the petition in July 2005.

After a petition to list a species is filed, the Fish and Wildlife Service (acting on behalf of the Secretary) has ninety days to make an initial finding whether the petition presents "substantial scientific or commercial information indicating that the petitioned action may be warranted" (this is known as a "90-day finding"). 16 U.S.C. § 1533(b). If the Service answers this question in the affirmative, it has twelve months from the date the petition was filed to decide whether to grant the petition and, if so, issue a proposed rule listing the species (known as a "12-month finding"). Id.

As is typically the case, however, we received no official response (other than an acknowledgement of receipt) to our Petition. Accordingly, on December 15, 2005, the Center for Biological Diversity, NRDC, and Greenpeace sued the Fish and Wildlife Service for failing to respond to the Petition within the time required by the ESA.[66] In response to the lawsuit, the Service issued a positive 90-day finding on February 9, 2007, and initiated a status review of the species. NRDC and the other petitioners, and numerous conservation groups, filed comments with the Fish and Wildlife Service during a public comment period that followed this finding. The parties also entered into a Settlement Agreement and Consent Decree that required the Service to make a preliminary decision about whether to propose the polar bear for protection under the ESA by the end of the year.

On December 27, 2006, the Fish and Wildlife Service issued a proposed rule to list the polar bear as a threatened species under the ESA, which was published in the *Federal Register* on January 9, 2007.[67] The proposed rule triggered another public comment period, which the Fish and Wildlife Service subsequently reopened twice, once to allow for the official submission of new

[66] *Center for Biological Diversity v. Kempthorne*, Civ. 05-5191 JSW (N. Dist. Cal. Dec. 15 2005) (Complaint).
[67] Proposal to List the Polar Bear as a Threatened Species, 72 Fed. Reg. 1064-1099 (Jan. 9, 2007).

information and once to allow public comment on the USGS studies discussed above. During these various public comment periods over 600,000 people submitted comments to the Fish and Wildlife Service, the overwhelming majority supporting the listing of the polar bear. Almost 400,000 of these comments were submitted by NRDC members and activists.

The Endangered Species Act requires that "[w]ithin the one-year period beginning on the date on which" a proposed rule to list a species is published in the Federal Register, the Fish and Wildlife Service must either issue a final rule listing the species or withdraw it's proposed rule." 16 U.S.C. 1533(b)(6)(A). The Fish and Wildlife Service may extend this mandatory deadline for six months if it finds that there is "a substantial disagreement regarding the sufficiency or accuracy of the available data relevant to the determination." 16 U.S.C. §1536(b)(6)(B)(i). Thus, in the absence of such a substantial disagreement, the Fish and Wildlife Service was required to make a final decision about whether to protect the polar bear under the Endangered Species Act no later than January 9th, 2008.

On January on January 7, 2008, the Fish and Wildlife Service announced that the listing decision would be delayed.[68] While the agency did not give a firm date for publication of the final listing determination, it stated that it "expected" to make a final decision "within the next month." The Fish and Wildlife Service did not claim that there was any substantial disagreement justifying a delay of the final listing determination.

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[68] Statement for Polar Bear Decision (January 7, 2008) (available at http://www.fws.gov/news/NewsReleases/showNews.cfm?newsId=54D2A6BD-E928-94E6-6BA905F3F540B8F7)

It is worth noting, however, that a delay of a month is precisely long enough to allow the Minerals Management Service to proceed with Lease Sale 193 in the Chukchi Sea. Despite this, however, the Mineral Management Service has refused to delay Lease Sale 193. NRDC believes that it is thus incumbent upon Congress to ensure that the Department of Interior withdraw its Record of Decisions on Lease Sale 193 and that the sale not be allowed to proceed until the Mineral Management Service fully accounts for the risk that it poses to the Chukchi Sea polar bear population under the Endangered Species Act, including any impacts that oil and gas development would have on polar bear critical habitat.

Thank you for this opportunity to address the Committee on the conservation of polar bears.

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Senator BOXER. Thank you so much, Mr. Wetzler.

I am going to have my Ranking Member question first, because he needs to leave, and then I will finish up. But I did want to recognize students in the back there from James Logan High School, Union City, California. I am very proud that you came in and that you care about the environment. We are very pleased that you are here.

Senator Inhofe.

Senator INHOFE. Thank you, Madam Chairman.

Dr. Armstrong, when you were talking, this chart up here, first of all, did you say that you had a paper that you wrote in 1978?

Mr. ARMSTRONG. I was writing books on long-range forecasting then.

Senator INHOFE. You were writing books in 1978?

Mr. ARMSTRONG. Well, I have been in this field for 48 years now.

Senator INHOFE. Wow. I thought maybe I heard wrong. You are the forecasting expert, I recognize that.

When I saw this before your testimony, the fact that they're using the 5-years, it is my understanding that three of those years showed normal sea ice coverage with high numbers of polar bear births and only two showed receding with a slightly less births. But the USGS used the 2-years. Is this correct? Or is my information wrong?

Mr. ARMSTRONG. I know there are a lot of questions about the quality of the data. My major point is, you cannot possibly use 5 years of data to estimate a causal relationship.

Senator INHOFE. But even with those 5 years of data, you cherry-picked the two worst years, that would be even more egregious?

Mr. ARMSTRONG. Yes.

Senator INHOFE. And I want to get back with another question. Richard Glenn, it is kind of interesting, your background, I understand you were at the University of Alaska and University of Nebraska, San Jose State and also a subsistence hunter. So you have been on the ground for quite some time.

In your testimony, you take issue with the FWS focus on the multi-year pack ice, and their neglect of the bears' activity on marginal ice. You also discuss how polar bears travel great distances to move between populations. Could you elaborate a little bit on that, why that is significant?

Mr. GLENN. The polar bear is an opportunistic hunter. It will follow its nose wherever it can find food. And the scientists have documented, for example, a polar bear denning in the Beaufort Sea, in the central Beaufort Sea, and that polar bear then drifting with the ice pack as far as the Wrangell Island area. Then as soon as the polar bear gave birth, the mother and cubs made a beeline back to the Beaufort Sea.

Now, this shows that polar bears can migrate between what you see as wedges on the map as population stocks. And it shows that part of their lifestyle is to move great distances. So how do you count polar bear population stocks when you have this flux between these different areas?

Senator INHOFE. That is interesting. In the testimony, and I don't remember whose it was, we talked about the number of things that are there for protection today, the Marine Mammal Act has been referred to several times, there are several international conservation agreements, educational outreach efforts. What are some of the ways in which the bear is protected already, and do you think we really need this ESA listing in addition to those that are already in place.

Mr. GLENN. Right, thank you. Several of the presenters today have talked about the various agreements and acts that are currently in place for protection of the polar bear. And they include the organizations of the Native people across the circum-Arctic and agreements that they have made about the harvest. What is lacking, though, is the ability, for example, to stop the poaching of polar bears by the Russians, where so many of the bears that live in our area are suffering from today. The agreements in place today are doing things like limiting to sustainable numbers the number of polar bears that are taken by subsistence hunters, by my people, the people that live along coastal Alaska and Arctic Canada.

So the list is long. There is the Alaska Chukotka polar bear population studies, United States-Russian Polar Bear Conservation and Management Act, there is of course the Marine Mammal Protection Act.

Senator INHOFE. You think those are adequate, that are there right now?

Mr. GLENN. Yes.

Senator INHOFE. And Dr. Armstrong, in your, well, first of all, you probably don't know this, I have been critical of computer modeling for quite some time and the deficiencies that are there, not just insofar as polar bears are concerned, but insofar as anthropogenic gases and what effect they actually have on climate change.

In your testimony, you point out that the USGS study included various assumptions. Can you briefly outline those assumptions?

Mr. ARMSTRONG. Yes. There were five assumptions. The first assumption is that global warming will occur. The second assumption is that polar bears will obtain less food by hunting from reduced sea ice platform. The third is that bears will not be able to adequately obtain supplementary food, using other means from other sources.

Four, the designation of polar bears as an endangered species will solve the problem and will not have any detrimental effects. And five, and I think probably the most important one, is that there are no other policies that would produce a better outcome than those based on the endangered species classification.

Senator INHOFE. Well, I might disagree, I think your first one is more significant. But that is fine.

I appreciate that very much. I regret that I won't be able to stay afterwards, to come and thank you individually for coming. But you have come a long way, and I appreciate all five of you being here and your testimony. Thank you for allowing me to go first, Madam Chairman.

Senator BOXER. Senator, thank you so very much.

Well, I think if we heard some of this testimony way back when from people like Dr. Armstrong and Mr. Glenn, we never would have saved the bald eagle. And I am going to pursue that.

Mr. Glenn, you said in your statement that you are an officer of the Arctic Slope Regional Corporation. And I read what that organization does, so I think we will put it in the record. The Arctic Slope Regional Corporation is committed to developing the resources and bringing to market, meaning oil, gas, coal and base metal sulfides. And bringing them to market in a manner that respects the Inupiaq subsistence values while ensuring proper care of the environment.

I think it is important to note that everybody who comes here has a certain background. When you come to this table to come to the polar bear and you belong to a corporation that wants to develop the resources, I just think it needs to be placed in the record. So I am going to place in the record what this Arctic Slope Regional Corporation does.

[The referenced material follows:]

Senator BOXER. Now, Dr. Scott, you are a Ph.D. in what? Dr. Armstrong.

Mr. ARMSTRONG. I went to MIT, so I basically had three areas, one was economics, another was social psychology and the other was marketing.

Senator BOXER. Economics, social psychology and marketing. Are you a biologist?

Mr. ARMSTRONG. No.

Senator BOXER. Are you a polar bear expert?

Mr. ARMSTRONG. No.

Senator BOXER. Are you an expert in wildlife of any sort?

Mr. ARMSTRONG. No.

Senator BOXER. Are you an ecologist?

Mr. ARMSTRONG. Pardon me?

Senator BOXER. Are you a climatologist?

Mr. ARMSTRONG. No, I am not.

Senator BOXER. So you are bringing your marketing experience here.

Mr. ARMSTRONG. No, I am bringing my forecasting methods experience.

Senator BOXER. But you are not, I just want to say for the record, an expert on the polar bear, you have never studied the polar bear, you have never gone out to see what is going on. Have you read the USGS report that talks about the polar bear?

Mr. ARMSTRONG. That is what we analyzed. But I think that is an advantage for me——

Senator BOXER. Whoa, whoa, whoa. No, no, no. I am not asking what you analyzed. I am asking you if you read the USGS report on the polar bear——

Mr. ARMSTRONG. Well, we read——

Senator BOXER [continuing].—before you made your statement that there is a high degree of uncertainty? Did you read the USGS report that says that two-thirds of the world's current polar bear population will be gone by mid-century if the ice continues to be lost at the rate it is now?

Mr. ARMSTRONG. That is what we did our audit on. That was what I reported on.

Mr. ARMSTRONG. I did. It is all marked up here.

Senator BOXER. You did. OK, very good. So I would like to ask Dr. Kelly and the other members of the panel, Mr. Wetzler and Ms. Williams do you feel that there is a high degree of uncertainty or instability about the information you are looking at on what is happening with the polar bears? I will start with Dr. Kelly.

Mr. KELLY. No. It is a remarkable amount of information on those populations, due to the efforts, primarily, of USGS biologists over a number of years. There are always uncertainties in any kind of data. I think it is important to recognize that there is a bit of a culture difference, I think, going on here between the way social scientists approach modeling and the way biologists and ecologists do.

Senator BOXER. Yes.

Mr. KELLY. I was a dean for several years in a school of arts and sciences. I struggled regularly with this difference in culture and language between economics and natural scientists. They both have their developed theories and approaches to modeling. As Senator Lautenberg so well put it, models are valuable and used in many, many different arenas. But there are these different disciplines that use them differently, they have different languages and they typically don't talk together very well.

So if you go through the literature in ecology, you won't find a lot of references to Dr. Armstrong's book and that approach, which isn't to say it is not a good approach.

Senator BOXER. OK, so just to sum it up, because we don't have a lot of time to have professorial back and forths, you find the information not to be confusing in terms of the threats? You don't find it to be uncertain at this point? Your research shows that the polar bear is threatened and will continue to be if the ice loss continues, is that correct?

Mr. KELLY. That is correct.

Senator BOXER. OK. Do you agree with that, Ms. Williams?

Ms. WILLIAMS. Yes, Senator Boxer, we are fortunate to have had several major reports in the last few years published that show great certainty on changes in the ice, on changes in the climate. These include the Intergovernmental Panel on Climate Change, the Arctic Climate Impact Assessment, they all show tremendous changes, increases in temperature, loss of sea ice, and the Arctic is changing at the fastest rate. The Arctic is the most vulnerable to climate change impacts throughout the world.

I also want to bring attention to a series of reports that the IUCN Polar Bear Specialist Group has been issuing on a regular basis. In 2004 and 2005 and 2006, IUCN, again, the world's preeminent body of polar bear specialists, have drawn attention to their concern on the future of the polar bear. In 2005, IUCN reclassified, actually it was 2006, the polar from least concern to vulnerable. In 2004, Andy Derocher, one of the leading polar bear scientists from Canada, said that predictions are uncertain, but we conclude that the future persistence of polar bears is tenuous.

So for years now, we have been hearing the concerns of people who are out there studying and observing the changes in body condition, and there is empirical evidence and it is quite certain that polar bears are suffering as a result of lost time on the sea ice.

Senator BOXER. Mr. Wetzler, I assume you agree with that. I do have a question about the drilling. There is a report I am going to place in the record published by the National Academy's Press called Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. In there, in that report, and it is done with a whole consortium of groups, they say climate warming at predicted rates in the Beaufort Sea region is likely to have serious consequences for ring seals and polar bears, and those affects will accumulate with the effects of oil and gas activities in the region.

And therefore, when you raised the issue of this lease sale, I understand, as representing the Endangered Species Project of NRDC, you see that this has a consequence and you are concerned, as I am, about this situation where we see a rush to a lease sale and a delay to a listing. I wanted you to expand on that.

I feel very strongly that when bureaucrats break the law, there ought be consequences. I think the consequences should be a lawsuit, and I am wondering whether you have heard if there would be that possibility. Because this thing is a nightmare.

Suppose they issue this lease and it has no conditions to protect the polar bear and the lease is good for many years. We know how that goes. And then we find out 2 weeks later that in fact, there is a finding made that this is true, that there is in fact a connection. It would be a disaster, and we would have to now go, I guess you would, I would try to overturn it legislatively, that is hard. You would try to overturn it, I am sure, in a lawsuit. But what are the chances that we could see some lawsuits here because of this outrageous missing of the deadline, and then this strange, miraculous timing of this oil lease?

Mr. WETZLER. I think, Senator, you are very like to see lawsuits on both issues. The Natural Resources Defense Council and the Center for Biological Diversity and Greenpeace have already informed Secretary Hall that if he does not rectify his illegal action by missing the deadline, we are going to sue him. We have to wait 60 days before we can file that lawsuit. But in the first week of March, if there is not a decision, we are going to take him to court.

And as far as the lease sale goes, I think that there will also be legal action by a broad coalition of groups in Alaska who are opposed to the lease sale, which is not just conservationists, but also Native groups and some government groups as well.

Senator BOXER. Well, I think that is very important. Because, and I just want to say to the environmental organizations who are here or who may be in the audience or supporters, you are really the wind at my back. I don't know what I would do with this Administration and this tough Senate right now in terms of living up to the letter of the law. This is not a question of oh, gee, I will wait until tomorrow. The law says the decision should have been made, and there is this connection.

So in closing, I want to take another look at the polar bear in all its glory and just say, this is pretty straightforward deal here. I guess, Mr. Glenn, when you say the polar bear can live on thin ice, which is essentially what you are saying, because if you go back to the loss of ice, I don't think anyone here is disputing, I don't even think Dr. Armstrong or Mr. Glenn are disputing the fact that the ice has been lost, but Mr. Glenn says, oh, the polar bear can live on this thin ice.

I guess I would like to ask you, Mr. Wetzler, since you are in charge of this project, what your response is to that. Can this polar bear live the way this polar bear has lived on thin ice that may or may not come back because of the climate 1 year or another?

Mr. WETZLER. If I can answer that by saying, and this goes back to your earlier question that, I have reviewed a lot of Endangered Species Act petitions and a lot of decisions by the U.S. Fish and Wildlife Service under the Endangered Species Act. This petition is remarkable for the unanimity and the strength of the scientific evidence supporting it. I don't think that there is any scientific question that the polar bears are endangered under the Endangered Species Act.

I think to answer your specific question about the difference between seasonal and permanent ice pack that Dr. Kelly would be a more appropriate person to ask.

Senator BOXER. OK, I will ask Dr. Kelly that question. The difference between the permafrost, or the living on the sea ice, the thin ice that might come 1 year or the next for the polar bear.

Mr. KELLY. Well, the question is not just a matter of the thickness, but it is also the regional extent. And the ice is retracting such that their habitat is shrinking at an alarming rate and will be gone during the summer before the century is over.

Senator BOXER. So let's take a look at the polar bear on the thick snow there, just looking to go in to get its prey, is what we pretty much think is happening, that one, yes. And I think we should keep this in our mind. I think that we all believe, because we are at the top of the chain, that nothing else matters. That is not true. And we all know this is not true. And we could have so much hubris that at the end of the day, we are the ones who are threatened.

I feel my work is not only about saving God's creation, but also about protecting human beings. Because at the end of the day, it is just all connected.

So I just want to thank all of our witnesses, regardless of their perspectives, for coming here today. And this Committee is dedicated to dealing with the issue of global warming. We are having a very important briefing this afternoon. Everyone is invited to come. We have the chair of the IPCC who will be before us, and he is going to go into what the IPCC has found about this.

So we really appreciate your being here and we stand adjourned.

[Whereupon, at 12:15 p.m., the committee was adjourned.]

TESTIMONY OF
JAMIE RAPPAPORT CLARK
EXECUTIVE VICE PRESIDENT
DEFENDERS OF WILDLIFE

FOR THE ENVIRONMENT AND PUBLIC WORKS COMMITTEE
UNITED STATES SENATE

HEARING ON
"EXAMINING THREATS AND PROTECTIONS FOR THE POLAR BEAR"

JANUARY 30, 2008

Madam Chairwoman and Members of the Select Committee, I am Jamie Rappaport Clark, Executive Vice President of Defenders of Wildlife. Founded in 1947, Defenders of Wildlife has over 1 million members and supporters across the nation and is dedicated to the protection and restoration of native animals and plants in their natural communities.

Thank you for the opportunity to submit testimony for the record. This hearing highlights the misguided and conflicting priorities of the current administration. There is a tragic irony to the situation today and a need to assess both the urgent importance of the proposal pending in the Department of the Interior to take action to prevent the extinction of the polar bear and the simultaneous proposal by the Minerals Management Service (MMS) in the same Interior Department to open to large-scale offshore oil and gas operations nearly 30 million acres of core habitat critical to the survival of polar bears. There is something dreadfully wrong with this picture.

On the one hand, it has to be abundantly clear to the Interior Department that global warming due to human activities threatens the survival of well documented, dwindling numbers of polar bears, and yet they are irresponsibly dragging their feet on listing polar bears as a threatened species under the Endangered Species Act. On the other hand, the same Department is now irresponsibly and unnecessarily rushing forward to sell oil and gas leases in the Chukchi Sea, in the heart of critically important and essential polar bear habitat. Not only would leasing increase the risk to polar bears from oil spills, pollution, and habitat destruction and further disturb already stressed populations, but also it would lead to even more burning of fossil fuels and even greater emissions of greenhouse gas pollution, exacerbating global warming and the melting of polar bears' Arctic ice habitat.

Defenders of Wildlife strongly believes the administration is wrong on both counts. As we have stated in comments to the U.S. Fish and Wildlife Service (FWS), testimony before the House of Representatives and as we reiterate here polar bears should be listed as a threatened species under the Endangered Species Act, without further delay. Furthermore, as a matter of law, once polar bears are listed, the administration must not proceed with any new oil and gas leasing in the Chukchi Sea or other areas of polar bear habitat until it has fully complied with the Endangered Species Act's consultation requirements to ensure that such leases will not jeopardize the continued existence of polar bears and other listed species. Consequently, it is the height of irresponsibility for the administration to try to evade consultation requirements by approving new oil and gas leasing in this region before polar bears are listed.

Madam Chairwoman, the administration's delay in listing polar bears on the one hand while, on the other hand, pushing forward with new oil and gas leasing in the heart of polar bear habitat, at the very least creates an appearance of, once again, allowing politics to trump science in endangered species decision-making. As a longtime career biologist with the federal government before becoming director of FWS, I know the difficulties faced by the dedicated professionals in FWS, the National Marine Fisheries Service, and other federal agencies implementing the Endangered Species Act. Consequently, I am reluctant to criticize them. However, I cannot ignore what this administration's political appointees have done to the administration of the Endangered Species Act and our other conservation laws. This administration has repeatedly engaged in political manipulation of science and conservation. For example, former Deputy Assistant Secretary of the Interior Julie McDonald was found by the Interior Department's own Inspector General to have inappropriately interfered politically with the professional assessments, conclusions, and recommendations of the Department's biologists, scientists, and wildlife managers in endangered species listing and critical habitat decisions--decisions which the Department has now been forced to revisit. Moreover, this administration has consistently starved endangered species and other conservation programs, reducing staff and budget to untenable levels. Thus, when the administration delays listing polar bears under the Endangered Species Act while, at the same time, promoting new oil and gas leasing in polar bear habitat, it is reasonable to suspect that it is once again putting political interests before conservation. For this reason, Defenders of Wildlife welcomes today's hearing and urges the Members of the Environment and Public Works Committee to make clear that such political interference with conservation will not be tolerated, in the Arctic or elsewhere.

Defenders of Wildlife has been particularly concerned with the Arctic and the fate of polar bears. The Arctic has become "ground zero" for the most visible adverse early effects of global warming, a place where dramatic coastal erosion threatens human communities and where the accelerating disappearance of sea ice has become emblematic of the underlying problems directly attributable to our society's destructive dependence on carbon-based fossil fuels. Polar bears are the most visible, and most poignant, symbol of the devastating impact global warming is already having on wildlife. It is no accident that the world's leading soft drink seller, Coca-Cola, has adopted polar bears as a marketing image. People respond to these magnificent creatures. Thus, as reports of melting Arctic sea ice proliferate and images of polar bears starving or drowning find their way into the public consciousness, polar bears are awakening us all to the threat from global warming. Or almost all of us.

Unfortunately, there is still ongoing denial by the Bush administration. By continuing to delay listing polar bears as threatened, and at the same time pushing forward new oil and gas leases in essential polar bear habitat, the Bush administration is continuing its outrageous pattern of denial and foot-dragging in response to global warming, while actually promoting the burning of fossil fuels that will only make the problem worse -- for wildlife and humans.

Quite simply, it is past time for this administration to list polar bears as a threatened species, to follow the requirements of the Endangered Species Act and carefully review proposed oil and gas leases and other federal actions to ensure that they will not jeopardize the continued existence of polar bears, and to refrain from any new oil and gas leasing in the Chukchi Sea and other polar bear habitat until adequate measures are in place to prevent harm from such activity to polar bears and their habitat. If the administration will finally show responsible leadership, the polar bear can serve not just as a symbol of the harmful impacts of global warming, but as a beacon of hope for helping all wildlife survive global warming.

I. Polar Bears Should Be Listed as Threatened Under the Endangered Species Act, Without Further Delay.

Responding to a petition filed by the Center for Biological Diversity, Greenpeace, and the Natural Resources Defense Council, FWS has proposed listing polar bears as a threatened species. FWS has received more than 600,000 comments on the proposal, nearly all of which favor listing. Defenders of Wildlife submitted comments in support of the proposed listing, in April 2006 and October 2007.

As we have stated in our comments on the proposed listing, there are numerous factors that support listing polar bears as threatened. These include the continued hunting of polar bears and international trade in polar bear parts, potential for increased vulnerability to disease and parasites resulting from habitat shifts due to global warming, increased exposure to human-caused disturbance and pollution, and the inadequacy of existing regulatory mechanisms to respond to the threat from global warming. Above all other factors contributing to the need to list polar bears as threatened, however, is the unequivocal and extensive loss of polar bear habitat due to global warming.

The Arctic sea ice which provides habitat for polar bears is literally melting away. Research conducted by experts at the U.S. National Snow and Ice Data Center in Colorado shows that for the second year in a row Arctic sea ice has failed to re-form after the summer melt. Last September, satellite images showed Arctic ice cover to be at its lowest extent since monitoring began in 1978, a reduction of 8.7 percent per decade. Scientists confirmed that summer sea ice retreated even more during summer 2007.

The extent of sea ice on the Arctic Ocean, of course, fluctuates with the season. The ice melts during the six months of daylight, reaching its minimum point in September. Normally, during the winter, sea ice forms to compensate for what was lost over the summer, but last winter the Arctic experienced warmer than usual temperatures preventing ice from forming and causing the ice that did form to be thinner. Reduction of the extent of sea ice in both the winter and summer is an indicator that the Arctic is experiencing a positive feedback effect, whereby warmer temperatures melt sea ice, causing more open water that absorbs sunlight, which, in turn, causes more ice to melt. In addition, emissions of black carbon, or soot, also may be accelerating the melting of sea ice by reducing its reflectivity. If this cycle continues as predicted, models indicate that there will be no sea ice left by 2070, or earlier. Already parts of the Arctic Ocean remain ice-free year round, such as a large area in the Barents Sea, home to an estimated 2,000-5,000 polar bears.

Loss of sea ice results in dire consequences for polar bears. Sea ice provides a platform from which polar bears hunt for ringed seals and other prey. As seals follow the receding sea ice, they may be too far from land for polar bears to reach them. Polar bears, though good swimmers over short distances, are not able to traverse large open expanses of water. In 2004, MMS found four bears that had drowned off the northern coast of Alaska where the ice cap had retreated 160 miles north of land. Unable to reach the sea ice, polar bears that remain on land will likely come into conflict with humans, leading to killing of so-called nuisance bears.

In particular, lack of sea ice will have a negative impact on female bears. MMS has found that, in the last ten years, 60 percent of female polar bears were denning on land and 40 percent were denning on ice, where previously the percentages were reversed. Polar bears that den on land have more difficulty traveling between land and ice, forcing them to leave the ice and stop hunting earlier before the ice has retreated too far for them to find their preferred denning areas on land. Less and thinner ice may also disrupt the rearing of polar bear cubs for those populations that den on the ice.

Here is the most dire warning of all: Reductions in Arctic sea ice and increases in the rate at which Arctic sea ice is disappearing led the U.S. Geological Survey to conclude that U.S. populations of polar bears will be extirpated by 2050. The government's own scientists predict that, if we continue with business as usual in emitting greenhouse gas pollution, by mid-century, polar bears will no longer exist in Alaska. **Case closed**. Polar bears must be listed as threatened under the Endangered Species Act. In addition, immediate steps must be taken to halt their downward spiral. These include refraining from oil and gas leasing in the Chukchi Sea and changing our energy policy to reduce greenhouse gas pollution. If we act now, there is hope for polar bears, the Arctic ecosystem, and ourselves and our children.

II. The Bush Administration Should Refrain From Oil and Gas Leasing in the Chukchi Sea and Any Other Polar Bear Habitat Until It Has Fully Complied With the Endangered Species Act to Protect Polar Bears and Their Habitat

Once a species is listed under the Endangered Species Act, it is entitled to a number of important protections. First, it is illegal for anyone to take an individual of the species. Take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(19). Prohibited take includes habitat destruction which actually kills or injures individuals of a listed species. So, for example, oil and gas development in the Chukchi Sea which results in an oil spill that kills or injures polar bears would be an illegal take under the Endangered Species Act, unless incidental take has been authorized pursuant to Section 7 of the Act.

In addition to the prohibition against take, listed species receive the additional protection provided by the consultation requirements of Section 7 of the Endangered Species Act. Section 7 requires federal agencies to consult with either the Secretary of the Interior, acting through FWS, or, in the case of certain marine species, the Secretary of Commerce acting through the National Marine Fisheries Service, to ensure that any action "authorized, funded, or carried out" by a federal agency "is not likely to jeopardize the continued existence" of a listed species or adversely modify or destroy its designated critical habitat. 16 U.S.C. § 1536(a)(2). Consequently, once polar bears are listed, any proposed oil and gas leases in the Chukchi Sea or other polar bear habitat would have to undergo Section

7 consultation first, to ensure that the leases are not likely to jeopardize the continued existence of polar bears or any other listed species in the region.

Even before polar bears are listed, Section 7 requires federal agencies to confer with FWS on possible impacts of federal actions which are likely to jeopardize polar bears or any other species proposed for listing. 16 U.S.C. § 1536(a)(4). Thus, since listing of polar bears has been proposed, MMS and FWS must determine whether oil and gas leasing in the Chukchi Sea is likely to jeopardize polar bears and, if so, confer on the leasing and its impacts. Once polar bears are listed, MMS must consult with FWS to ensure that the leasing is not likely to jeopardize the continued existence of polar bears. In other words, the Endangered Species Act requires federal agencies to stop and think about the effect of their actions on listed species and species proposed to be listed. It would fly in the face of the precautionary purpose of the Endangered Species Act if the Interior Department is able to take advantage of its own delay in making a listing decision on polar bears to expedite oil and gas leasing in the Chukchi Sea, without first fully evaluating the potential harm to polar bears. At minimum, given the proximity of the listing decision and the leasing proposal, the Bush administration should delay any oil and gas leasing in the Chukchi Sea or any other polar bear habitat until the listing decision has been made and, assuming polar bears are listed, Section 7 consultation requirements are fully met.

The potential for harm to polar bears from oil and gas leasing in the Chukchi Sea is substantial. MMS is proposing to open nearly 30 million acres of core habitat critical to the survival of polar bears to oil and gas development. Such development is highly risky and detrimental to polar bears and other Arctic wildlife. Oil and gas development routinely produces massive air pollution emissions, including increased emissions of greenhouse gases that cause global warming. The sensitive Arctic marine environment is subject to serious damage, from activities ranging from seismic survey blasts to routine toxic discharges of spent drill muds, borehole cuttings, and wastewater, dumped directly into one of the most pristine and biologically sensitive marine environments on the planet. The risk of damage from oil spills, leaks, fires, and other accidents, exacerbated by an industry history of lax oversight and enforcement, poses a serious threat to Arctic wildlife.

Most disturbing of all, no technology presently exists that can even begin to successfully clean up spilled oil at sea in the meteorological and sea-state conditions prevalent in the Arctic. Furthermore, no oil spill technology currently exists to adequately respond to a spill in broken-sea-ice conditions such as those prevailing in the Chukchi Sea. Once an oil spill moves under the ice sheet, which is essential to the breeding, feeding, and sheltering of polar bears and the entire Arctic marine life community, there is no way to even track its movements. Oil will not biodegrade but will remain highly toxic for up to a century or more, continually leaking out at unpredictable intervals to poison our wildlife and foul delicate lagoons and hundreds of miles of inaccessible shorelines. For polar bears, as well as the resident walrus and shorebird populations, and for the migrating bowhead and beluga whales in the Chukchi Sea, the consequences are unthinkable.

In addition to the potential for direct harm to polar bears and their habitat from oil and gas development in the Chukchi Sea and elsewhere, there is the indirect, but equally devastating, impact of promoting additional burning of fossil fuels, which increases greenhouse gas pollution that causes global warming. We have reached a point, Mister Chairman, where we cannot continue business as usual. We cannot continue to promote the burning of fossil fuels if we are going to stabilize atmospheric greenhouse gas concentrations and stop human-caused global warming. The plight of polar bears is a warning to us that we must act now to reduce our use of fossil fuels and consequent production of greenhouse gas pollution.

This is so much bigger than a singular focus on the polar bear, regardless of the importance of this species itself. Given what we now clearly know about the drastic implications of global warming for human society worldwide, it is clear that the administration's stumbling approach to making these decisions concerning the polar bear and the Chukchi Sea are emblematic of something bigger and very troubling. Even with all the evidence out there on the seriousness of global warming, this administration still—incomprehensibly—refuses to believe it. Or, they do believe it and yet still will not take responsible action because of their commitment to serve private and political interests that are not in the best interests of the country or the future. Either way, it is a poor reflection on this administration and the American people are ill-served by it.

Conclusion

In conclusion we have come to a crossroads—for the polar bear, for all life in the Arctic seas, and for our own global climate future. It is long past time to begin seriously addressing global warming. The Bush administration should move forward immediately to list the polar bear as a threatened species and to fully comply with the requirements of the Endangered Species Act. The administration should also withdraw the proposed oil and gas leases in the Chukchi Sea, while it fully complies with the consultation requirements of the Endangered Species Act. The administration should also refrain from any further oil and gas leasing in the Chukchi Sea or other polar bear habitat until adequate measures are in place to protect polar bears and their habitat from the harmful effects of such development. Most importantly, this administration or, more likely, the next one, should work with the Congress to develop an energy policy that will reduce our use of fossil fuels, our production of greenhouse gas pollution, and that will protect polar bears, other imperiled wildlife, and, ultimately, ourselves and future generations from the harmful impacts of global warming.

Thank you again for the opportunity to submit testimony for the record on this important issue.

WRITTEN TESTIMONY FOR

THE SENATE COMMITTEE ON THE ENVIRONMENT AND PUBLIC WORKS

HEARING ON EXAMINING THREATS AND PROTECTIONS
FOR THE POLAR BEAR

JANUARY 30, 2008

Jack Lentfer
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As an Alaskan wildlife biologist with extensive polar bear experience, I am especially concerned about the threat of global warming to polar bears. I have directed polar bear research and management programs for the State of Alaska and the U.S. Fish and Wildlife Service, served as a member of the international Polar Bear Specialist Group, and helped negotiate the international Polar Bear Agreement. I have served on the Scientific Advisory Committee and also as a Commissioner of the U.S. Marine Mammal Commission. During my time with the Marine Mammal Commission, it dealt with a number of polar bear issues, all of which I was involved with. I have published peer-reviewed articles for scientific journals and popular articles on polar bears

The U.S. Fish and Wildlife Service and the U.S. Geological Survey (USGS) have made a comprehensive and science-driven case to list polar bears as threatened under the terms of the Endangered Species Act because global warming is destroying their sea ice habitat. Sea ice is essential habitat for ringed and bearded seals, the primary prey of bears, and provides a platform for hunting them. Ice facilitates seasonal movements for bears, provides a platform for most mating, and in some areas provides maternity denning habitat. The overall conclusion of the USGS research effort is that projected changes in future sea ice conditions, if realized, will result in the loss of approximately 2/3 of the world's current polar bear population by the mid 21st century. This assessment of future polar bear status may be conservative because the observed trajectory of Arctic sea ice decline appears to be underestimated by currently available models.

Modeling indicates sea ice reductions will occur across the range of polar bears. Some of the best data for assessing population change are for the southern Beaufort Sea population off Alaska's north coast. The body condition of bears, recruitment of cubs, and demographic trends of this population are all declining as sea ice decreases. Other signs of population stress include a shift toward land-based denning, abandonment of areas with high rates of ice degradation, and starved and cannibalized bears. The USGS predicts that if ice conditions observed since 1979 continue, this population can be expected to decline about 1 percent per year and be at 1 to 10 percent of present numbers by 2100. If ice conditions remain similar to those of 2004 and 2005, the population would decline severely within 45 years. Various forecasts of sea ice conditions predict that this population could be extirpated within the next 50 to 100 years.

The U.S. Marine Mammal Commission (MMC), charged with making recommendations to the Secretary of Interior regarding the Endangered Species Act, has reviewed listing documents. One of the members of the Scientific Advisory Committee to the MMC is a preeminent Canadian polar bear scientist. The MMC states that USGS modeling to predict reductions in sea ice constitute the best scientific information available and that a strong legal justification exists for listing under the Endangered Species Act at the present time. Based on sea ice modeling projections, the MMC believes that the southern Beaufort Sea population should, at a minimum, be listed as threatened. If nothing were to occur to reverse the projected trend in sea ice loss, the MMC believes the population is already close enough to extinction to warrant listing as endangered. MMC believes the other Alaskan population (Chukchi Sea) faces risks similar to those of the southern Beaufort Sea population and also merits an endangered status listing.

Another issue of immediate concern is pending action in the Department of Interior for an oil and gas lease sale in the Chukchi Sea outer continental shelf before taking action to list under the Endangered Species Act. Polar bears could be affected by oil and gas activities as follows: (1) damage or destruction of essential habitat; (2) contact with and ingestion of oil from acute and chronic oil spills; (3) contact with and ingestion of other contaminants; (4) attraction to and disturbance by industrial noise and harassment by aircraft, over-ice vehicles, icebreakers, and other vehicles; (5) death, injury, or harassment resulting from interactions with humans; (6) increased hunting pressure; and (7) potential injury, mortality, and stress resulting from handling and interaction designed to evaluate and/or investigate all of the above. Before oil and gas leasing is approved for the Chukchi Sea each of these aspects should be considered thoroughly and include an evaluation of how global warming and development interact in conjunction to affect polar bears and the marine food web that supports them. It is of special concern that no method has been developed to remove spilled oil from ice covered water.

After several decades into the future, polar bears may occur only as a remnant population in the high Canadian Arctic. Protective measures now, that include listing under the Endangered Species Act and the Recovery Plan that follows, may help the species survive and recover if global warming and loss of sea ice habitat can be reversed.

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INUIT TAPIRIIT KANATAMI

Written Statement on:
Examining Threats and Protections for the Polar Bear

Prepared for:
U.S. Senate Committee on Environment and Public Works
Washington D.C.

Submitted by:
Ms. Mary Simon, President
Inuit Tapiriit Kanatami
Ottawa Canada

February 6, 2008

Dear Senate Committee Members

On behalf of Inuit in Canada, we are thankful to be given the opportunity to provide for you a written statement for the record in regard to your current deliberations on the examination of threats and protections for the Polar Bear in light of the proposed listing of the Polar Bear as *Threatened* throughout its range under the Endangered Species Act (ESA).

I am certainly hopeful that your Committee will consider our concerns from a Canadian Inuit perspective as we, along with our fellow Indigenous Alaskans, Greenlanders, and Russians, share in our own respective ways a very close, enduring, and important relationship and cultural link to the Polar Bear.

Please do appreciate in context that we as a people in Canada's Arctic have similar important on-going subsistence, cultural, livelihood, and spiritual links to many other terrestrial and marine mammals, fish, birds, and plant life. The Polar Bear (called *Nanuq* in our language) is one among many species important to us, and if we felt it was incumbent upon us to defend and promote our rights, our interests, and perspectives on any other species important to us, we would not hesitate to do so.

When we are concerned about our Arctic environment and ecosystems in the face of global warming, we are concerned for our wildlife and for our very own lives and way of life as Inuit because these elements are inseparable. As a result, we must approach emerging issues and changes in as much of a balanced way as we can from the perspective of our past and current state of affairs, and to examine and determine the best solutions and options as ways forward. This is an important way in which we arrive at our decisions and directions given the complexities and challenges we face in the Arctic, the successes we have thus far achieved, and the need to sustain our culture and way of life for our future generations.

Our organization, Inuit Tapiriit Kanatami (ITK), is the national organization that represents and advocates on behalf of Inuit in Canada. Similarly, our associated organization, the Inuit Circumpolar Council (ICC), Canada, represents and advocates on behalf of Inuit in Canada but on an international level along with other ICC associated organizations in Alaska, Russia, and Greenland.

On April 4, 2007, our two organizations jointly provided a written submission to the US Fish and Wildlife Service indicating our disagreement with the proposed listing of the Polar Bear as *Threatened* on the U.S. Endangered Species Act.

With some emphasis or rephrasing, we essentially had expressed the following:

- The Polar Bear is integral to Inuit because it has value culturally, spiritually, subsistence and nutritionally, for knowledge, for clothing, and for livelihood;

- Inuit have signed Land Claims Agreements with Canada and have a suite of Constitutionally protected rights under which we can continue the sustainable harvest and use of Polar Bears;
- Inuit in Canada have conserved and continue to conserve the Polar Bear at healthy population levels through proper and responsible wildlife management, co-management, research, monitoring, as well as through our sustainable harvesting measures and practices as a hunting culture;
- There are numerous sub-national, national, international, and user-to-user agreements, bodies, and processes that serve to conserve, manage, monitor, and regulate Polar Bear populations—it would be fair to say that the Polar Bear is among the most managed species in Canada's north, and the majority of the world's Polar Bears are in Canada;
- There is insufficient inclusion of Inuit Traditional Knowledge of Polar Bears in the proposed rule's considerations;
- There is no consideration or examination of the Polar Bear's ability to adapt to changing and ice-free conditions—the proposed rule focuses on the projected future demise of the species;
- Using long-term projections (i.e. the 45-year model) regarding the fate of our wildlife in relation to ice is an exercise in speculation and we see this as one precautionary projection which cannot be substantiated and do not support the use of such long term and uncertain predictions to base current high-impact decisions on the management and use of our critical wildlife resources;
- It is our concern that elevating the listing of the Polar Bear to *Threatened* will impose arbitrary, and scientifically unfounded, penalties and hardships upon Inuit;
- As a part of our responsibility for conserving and managing Polar Bears, we will take appropriate measures if and when the populations or subpopulations do become adversely affected for one reason or another;
- The environmental organizations and petitioners to the propose rule are using the Polar Bear and the ESA to apply public and political pressure on the current US Administration to address greenhouse gas emissions;
- Using the Polar Bear and the ESA for political and public campaigning purposes is, in our view, misguided and short-sighted;
- We see no conclusive or convincing evidence which demonstrates that a broad Polar Bear regulatory restriction will in fact reduce greenhouse gas emissions or become a practical solution to mitigate climate change—if anything that will be certain, Inuit will be the most adversely affected.

As an organization that represents Inuit and the realities of living in the Arctic, which includes the necessity of hunting, fishing, trapping, using the resources of the land and ocean, and observing and experiencing the changes that are happening as a result of global warming, we are very careful not to become alarmist and to be wary of those who perpetrate alarmist messages or campaigns for their own interests or causes.

During the course of the deliberations and discussions surrounding the proposed rule for the past year or so, even we were thinking of the motivations behind the need to up list the Polar Bear to Threatened on the ESA. Is it to stop American hunters from sport hunting in the Canadian Arctic? Is it some method to curb global warming? Is it meant for the environmental organizations to increase their publicity and financial return and test the hook of using the Polar Bear as an icon species that is already seen in zoos and coca cola commercials? Or is it a regulatory means for environmental organizations to legally stop drilling in the Alaskan off-shore?

The real issue for us in the Arctic is climate change that has the potential to affect us all, including our wildlife. Therefore, we continue to call for regulation and mitigation measures at the national and international levels in order to directly address greenhouse gas emissions and to find new technologies, harness new forms of clean energy and energy production, and for environmentally friendly alternatives to such things as vehicle engines that burn fossil fuels.

In closing, I want to thank the Committee for accepting our written submission at this time as you deliberate the issue of the threats and protections for the Polar Bear.

Sincerely,

M. Simon

Mary Simon
President
Inuit Tapiriit Kanatami

Arctic Slope Regional Corporation

» COMPANIES

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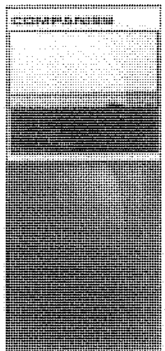

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arctic slope
regional corp.

October 22, 2007

Via email to Polar_Bear_Finding@fws.gov

Attn: Polar Bear Finding
U.S. Fish and Wildlife Service
Marine Mammals Management Office
1011 East Tudor Road
Anchorage, Alaska 99503

Re: Comments of the Arctic Slope Regional Corporation on the New Information Contained in United States Geological Survey Reports and the Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout Its Range

To Whom It May Concern:

On behalf of the Arctic Slope Regional Corporation (ASRC), I respectfully submit the following comments in response to the Notice of Availability of New Information issued by the U.S. Fish and Wildlife Service (USFWS) requesting comment on nine United States Geological Survey (USGS) reports concerning sea ice conditions and the effect of habitat change on the polar bear (Ursus maritimus). 72 Fed. Reg. 56979 (October 5, 2007). ASRC seeks a continued dialogue with the USFWS regarding the information contained in these reports and the proposed listing of polar bear as a threatened species under the Endangered Species Act (ESA), and greater appropriate peer review of the studies and reports in the USGS reports.

As noted in our comments on April 9, 2007, responding to the request for comments on the proposed listing of the polar bear as a threatened species, ASRC has an obligation to protect our Inupiat shareholders' interests by ensuring that USFWS's proposed rule is objective, based on the best available science, draws on all relevant scientific disciplines and is informed by—and respects—Inupiat traditional knowledge of our environment.[1] As discussed further below, ASRC is deeply concerned about the recent apparent decision by USFWS to rely heavily on the new, previously unpublished or uncirculated USGS reports in the final listing rule. Such a reliance on significant new scientific data assessments, which differ substantially from the previously available scientific information, forecasts and conclusion used to support the proposed listing rule, is not warranted unless greater peer review and consultation are provided.

1 *See* ASRC, Comments of Arctic Slope Regional Corporation on the Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout Its Range (April 9, 2007).

A very limited public comment period for such significant reports which were largely assembled outside of public scrutiny does not meet the tests of fairness or the law for listing.

1. Listing of the polar bear under the ESA should not be used as a land management tool or to drive climate change policy.

At the outset, ASRC continues to believe that the proposed listing on the basis of forecasted habitat loss arguably caused by human activities across the globe is an inappropriate use of the ESA. The agency will not be able to engage in any meaningful section 7 consultations following a listing, because to do so arguably would require that all anthropogenic activities contributing to the release of greenhouse gas emissions anywhere within the jurisdictional reach of the ESA be subjected to a section 7 consultation whenever the requisite federal nexus is present. This would be a virtually impossible task, and require an almost herculean determination of whether those particular activities, whether occurring on the east coast, the west coast, the midwest, Alaska or Hawaii, are likely to contribute to the loss of a certain percentage of the habitat of the polar bear and, if so (absent a critical habitat designation), how that loss of habitat will affect the polar bear. An almost identical impossible task will be required with respect to any judgments regarding the potential "take" of the polar bear as a consequence of activities that allegedly contribute to the loss of the polar bear's habitat. We are quite concerned about changes in climate conditions in the Arctic and have more reason than others to be aggressive about addressing climate change; however, the proper methods to address those issues are to deal with climate change conditions and causes directly, not to twist the ESA listing of the polar bear into an action directed at climate change.

2. The USGS reports lack meaningful observational data, including data incorporating the use of Inupiat traditional ecological knowledge.

Next, the USGS reports focus intensely on statistical analysis and modeling approaches to make key determinations regarding polar bear mortality. Many of these determinations, in the form of forecasts upon which the listing would turn, do not appear to factor in much, if any, observational data and are far more determinative than previously used scientific information. We believe that the USGS reports rely too exclusively on the use of models to identify the likelihood of polar bear survival (e.g., modeling to identify the relationship between ice conditions and cub recruitment). While we agree that the use of modeling is necessary and beneficial, models should be tested with other data, particularly observational data that happens to be available in this instance. ASRC requests that the USFWS's final listing rule discuss both the USGS reports based on modeling and reports based on previously used observational data. If there are conflicts between the two types of reports, then USFWS should discuss the conflicts and how those were resolved in the agency's final decision.

ASRC is also concerned that, in compiling these reports, USFWS and USGS have not made any concerted effort to gather traditional ecological knowledge from the Inupiat people. We yield to no one in our desire to protect and conserve the natural resources of the Arctic. Our people have vigilantly monitored, guarded and lived with those resources for centuries. There is no other group in the country with as much current and historical knowledge of the polar bear and its habitat as our Inupiat people. Our traditional knowledge encompasses wildlife, sea ice conditions and climate change and is built upon thousands of years of experience with the polar bear and its habitat. The importance of traditional ecological knowledge is recognized by the USFWS; for instance, the draft Status Assessment of polar bear was subject to peer review by independent experts in many fields including traditional ecological knowledge. *See* 72 Fed. Reg. at 1065. In providing for the co-management of species under the Marine Mammals Protection Act (which includes polar bear), USFWS "considers traditional ecological knowledge a significant contribution to our understanding of polar bears and other species and their habitat."[2] We believe that the USGS reports, and any final listing rule, should incorporate traditional ecological knowledge and that ASRC should be consulted and work with the agency in compiling that knowledge.

3. <u>The comment period for the USGS reports is insufficient for adequate review, analysis and comments on the major changes in scientific conclusions on the polar bear's viability from previous studies.</u>

Climate change and reducing greenhouse gas emissions is not something that will be changed overnight, or in a year for that matter, and so ASRC is concerned with the USFWS's desire to proceed quickly without ensuring a meaningful opportunity for parties to participate and comment on this proposed listing. The amount of time provided by USFWS for review and comment on the USGS reports is wholly unsatisfactory. While we appreciate the granting of a limited extension of the comment period, the short review period that was provided is inadequate for such a volume of information. These USGS reports mark a significant departure from conclusions on the polar bear's population trend from that set forth in the USFWS's Proposed Rule and Notice of 12-month Finding published on January 7, 2007. 72 Fed. Reg. 1064 (January 7, 2007). In the proposed listing rule, USFWS's predicted population trend showed that for seven populations the trend could not be determined, for five populations the trend was stable, for five populations the trend was declining, and for two populations the trend was increasing. 72 Fed. Reg. at 1070. The new USGS reports, however, paint a far bleaker picture of the polar bears survival, based on modeling and forecasting, to predict the loss of approximately 2/3 of the world's current polar bear population by the mid-21st century and, within that time frame, the extirpation the Southern Beaufort Sea subpopulation. As a policy matter, this significant change in the polar bear's population trend deserves appropriate peer review and a thorough review by all stakeholders, who are to be provided a "meaningful" opportunity to participate in the rulemaking process.[3] Access to information without time to review and comment does not allow for a "meaningful" participation.

Neither USFWS nor the USGS consulted with ASRC or the Inupiat people, in general, prior to the consideration of or publication of the reports. We were not granted an opportunity to request peer review or an independent third party review. Because the USGS reports are such a departure from the prior reasoning regarding the polar bear's population trends and sea ice condition in the Arctic and, as noted in the Notice of Availability of New Information, will be relied upon by USFWS in making the final listing decision, it is important that adequate review of the reports be completed.

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[2] USFWS, A Co-management Vision for the Sustainable Use of Sea Otter, Polar Bear, and Walrus in Alaska, 1997 – 2000, 5 (2000).

[3] <u>Idaho Farm Bureau Fed'n v. Babbitt</u>, 58 F.3d 1392, 1404 (9th Cir. 1995).

4 <u>ASRC has significant concerns regarding the methodology used in the USGS reports.</u>

We believe that the USGS reports, as presented, may not meet the standard for the best scientific and commercial data available, which Congress has directed that the Secretary use as a basis for ESA listing determinations, since there has been little opportunity to review the major assumptions and methodology contained in the reports.[4] ASRC joins in the comments filed by the State of Alaska with respect to the distinctions used to classify the polar bear into subpopulations as well as other specific disagreements over the methodology used in the USGS reports including the methodology used in modeling and forecasting.

In particular, we question the division of the range of polar bear into four ecoregions and the use of subpopulations in the latest USGS reports. There is simply no demonstrated basis in the proposed listing rule or the USGS reports to appropriately distinguish, within the levels of scientific accuracy required for listing, between polar bears found in different locations. As we noted in our previous comments, polar bear are highly migratory. Given the wide movement of the polar bear between areas, we do not see a sufficient, current and clear basis to determine that a member of a "subpopulation" is in fact distinct from the remainder of the polar bear species. If USFWS wishes to identify "distinct population segments" (DPS) for purposes of the ESA listing, there are specific principles to determine if a DPS exists.[5] There has been no decision by USFWS to identify polar bear DPS, and therefore it seems inappropriate that the USGS reports would rely on subpopulations.

The State of Alaska has also noted that there is substantial disagreement regarding the sufficiency and accuracy of the available information in the USGS reports, especially regarding the validity and predictive value of climate modeling, but also regarding population modeling based on modeled environmental changes. For example, there are models and studies of the likely timing and extent of sea ice recession that differ significantly with the conclusion of the USGS reports and USFWS's determination in the proposed listing rule. Use of models and conclusions drawn from those models should involve commentary from a wide spectrum of disciplines including other polar bear experts, climatologists, and statisticians over a sufficient length of time to allow proper scientific debate and reciprocal discussion.

We join with the State of Alaska in our concerns regarding the accuracy of the modeling and forecasting on which the USGS reports depend for their conclusions on the viability of the polar bear populations. As the State notes, looking more than ten years into the future is pushing climate change models beyond their ability to produce reasonable approximations of likely conditions. Claiming to foretell the effects of climate change 45 years into the future, as the USGS reports do, invites the use of highly speculative and uncertain assumptions and forecasts regarding climate change, ice modeling and uncertain possible impacts on the species which are too speculative to be used in the ESA listing decision. Such speculation, using highly uncertain ice and climate modeling, is not an appropriate basis to support listing a species whose population numbers are currently not in decline.

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[4] 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R. § 424.11(b).

[5] *See* 61 Fed. Reg. 4,721 (1996).

The ESA listing decision is to be based "solely on the basis of the best scientific and commercial data available."[6] Another statute, the Information Quality Act (section 515, P.L. 106-554), imposes requirements to ensure the quality and utility of information disseminated by federal agencies. These statutory requirements are not met in the issuance of the USGS reports. Policy guidelines further direct the USFWS to ensure appropriate data is used in the listing process.[7] ASRC has significant concerns regarding the methodology used in the USGS reports, but an appropriately through review of the methodology used in the reports requires a degree of technical expertise not readily available to stakeholders such as ASRC, in part because the reports conclusions were based primarily on modeling. USFWS has provided insufficient time for ASRC to assess the reports and provide substantive comments.

5. <u>The USGS reports do not indicate any impact to the polar bear populations from local or state activities or oil and gas activity.</u>

As a comment on the USFWS's proposed rule listing the polar bear as threatened under the ESA, ASRC would like to reiterate that local and state activities and oil and gas activity in the Arctic have not been linked to a decrease in the polar bear population. In reviewing the five factors for listing a species under the ESA, the USFWS did not identify local or state activities as having an impact on polar bear populations. Oil and gas activity was also found to pose no threat to the viability of the polar bear population. As noted in the proposed listing rule, "[d]ocumented impacts on polar bears by the oil and gas industry during the past 30 years are minimal." 72 Fed. Reg. at 1079. In fact, "[n]o lethal take associated with [the oil and gas] industry has occurred during the period covered by incidental take regulations." 72 Fed. Reg. at 1080. The proposed rule concluded that oil and gas activities "do not threaten the species throughout all or a significant portion of its range." 72 Fed. Reg. at 1080. The USGS reports do not change this finding, as no mention of local or state activities or oil and gas activity were made in the reports. In making the final listing decision, ASRC requests the USFWS reaffirm this point in the final listing rule, since it is not contradicted in the USGS reports in any manner.

6. <u>USFWS has failed to adequately consult with Alaska Natives.</u>

As noted in Executive Order 13175 (April 29, 1994), USFWS has an obligation to communicate on a Government-to-Government basis with the Alaska Native entities recognized by the Secretary of Interior on Federal policies that have tribal implications.[8] The eight Villages represented by ASRC are included on the Secretary of Interior's list of Indian Entities Recognized and Eligible to Receive Services from the United States Bureau of Indian Affairs and should be afforded the consultation benefits described in Executive Order 13175. USFWS even acknowledged this responsibility in the proposed listing rule, stating that "we readily acknowledge our responsibility to communicate meaningfully with recognized Federal Tribes on a government-to-government basis." 72 Fed. Reg. at 1099. In assembling the scientific

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6 *Id.*

7 59 Fed. Reg. 34,271 (1994).

8 "Policies that have tribal implications" refers to regulations, legislative comments or proposed legislation, and other policy statements or actions that have substantial direct effects on Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes.

information and assessments contained in the nine USGS reports, we believe that the agencies (USGS and USFWS) have not met these requirements to establish regular and meaningful consultation and collaboration with Alaska Natives.

In addition to the Executive Order requirement for consultation, it is the policy of the federal government to consult with Alaska Natives regarding ESA listing of subsistence species, such as polar bear. *See* Secretarial Order 3225 (2001). Under this policy, Alaska Native organizations have the opportunity to participate in the management of subsistence species that are proposed or listed species under the ESA. The management includes, but is not limited to: forming recommendations for management actions, plans or regulations; population and harvest monitoring projects; law enforcement activities; education programs; research, design, data collection and use of traditional knowledge; habitat protection programs; and recovery projects.

ASRC is concerned that USFWS has made no apparent attempt to consult with affected Alaska Native groups on the new USGS reports or the effect of those reports on the proposed listing or potential management of the species. The Inupiat, with our traditional knowledge of the Arctic and our wildlife, already play a large role in conserving the polar bear; a role which should be increased, not diminished, if the species is in peril. Traditional and common-sense knowledge is, as history shows, very important in the conservation and rehabilitation of a species. In addition, as noted in our previous comments, our people are active in polar bear conservation organizations such as the Alaska Nanuuq Commission.[9] ASRC encourages USFWS to seek full access to the breadth of knowledge and year-round, first hand traditional knowledge held by the Inupiat people before completing scientific reports such as the USGS reports and before taking action to list the polar bear as threatened under the ESA.

Conclusion

ASRC strongly believes that a listing as threatened for the polar bear, based on scientific information that has not been properly reviewed, does not meet scientific, legal or regulatory requirements of the ESA is not justified. Ultimately, a listing under these circumstances, would have very little impact on the population status of the polar bear yet, a listing under the ESA would negatively and disproportionately affect the Inupiat Eskimos who co-exist with the polar bear in the Alaskan Arctic. As such, we are gravely concerned with the USFWS reliance on USGS reports that have not been thoroughly reviewed, rely on untested modeling and forecasting which has been subject to limited peer review, and are substantially different in conclusion than scientific reports issued this year with the proposed listing rule.

ASRC continues its request to USFWS that rather than a rushed ESA listing of the species, that we work together to understand the polar bear and its habitat, and specifically work toward understanding the consequences of how development and greenhouse gas emissions generated far away from our lands and waters affect the habitat we share with the polar bear. ASRC reminds USFWS that under both Executive Order 13175 and Secretarial Order 3225 the agency is required to consult with Alaska Natives, a consultation that has not occurred to date.

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9 *See* ASRC, Comments of Arctic Slope Regional Corporation on the Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout Its Range, 19 and Appendix A (April 9, 2007).

ASRC looks forward to establishing regular and meaningful consultation and collaboration with USFWS and continuing this discussion at that time.

Sincerely,

Roberta Quintavell
President and Chief Executive Officer for
ASRC

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January 30, 2008

The Honorable Barbara Boxer
Chair, Environment and Public Works Committee
United States Senate
Room 456
Dirksen Senate Office Building
Washington, D.C. 20510

The Honorable James Inhofe
Ranking Minority Member, Environment and Public Works Committee
United States Senate
Room 456
Dirksen Senate Office Building
Washington, D.C. 20510

Dear Senators Boxer and Inhofe:

ASRC represents the interests of its 10,000 Inupiat Eskimo shareholders who live on Alaska's North Slope. Because this proposed listing under the Endangered Species Act presents potential changes, problems, costs, and uncertainties for our shareholders and the communities and villages in which they live, ASRC has previously submitted comments and testimony on the Administration's proposed polar bear listing. I am enclosing copies of these comments and I would appreciate it if they were made a part of the Committee's record of this hearing.

Sincerely,
ARCTIC SLOPE REGIONAL CORPORATION

TSweeney

Tara Sweeney
Director, Government Affairs

Corporate Headquarters • P.O. Box 129 • Barrow • Alaska • 99723-0129 • (907) 852-8533 or (907) 852-8633 • FAX (907) 852-5733 • 1-800-770-2772

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April 9, 2007

Via email to Polar Bear Finding@fws.gov

Attn: Polar Bear Finding
U.S. Fish and Wildlife Service
Marine Mammals Management Office
1011 East Tudor Road
Anchorage, Alaska 99503

Re: Comments of Arctic Slope Regional Corporation on the Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout Its Range

To Whom It May Concern:

On behalf of Arctic Slope Regional Corporation (ASRC), I enclose and transmit the following comments and recommendations regarding the United States Fish and Wildlife Service's (USFWS) proposed rule to list polar bear (*Ursus maritimus*) as threatened throughout its range under the Endangered Species Act (ESA). 72 Fed. Reg. 1064 (January 9, 2007). ASRC looks forward to a continued dialogue with USFWS regarding this proposed listing and the many impacts it could have, if adopted, upon the Inupiat Eskimo people.

Our formal comments focus on the biological, scientific and commercial data associated with this proposed rule, as well as our people's traditional knowledge of the polar bear.

The Introduction and Background sections of our comments provide information about ASRC, its Inupiat shareholders, their traditional knowledge about the polar bear and the legal basis for USFWS to address our shareholders' concerns.

The balance of this transmittal letter will touch upon a few important matters associated with the proposed listing which are not exclusively science based, but which provide important and relevant information for understanding our comments. We have separated this information from our formal comments to be in accord with what we understand are USFWS's guidelines for science-based comments on proposed listings.

1. Preparation of an EIS Would Benefit the Listing Proposal

The proposed listing of the polar bear as threatened constitutes "a major Federal action" which should be subject to the preparation of an Environmental Impact Statement (EIS) under the National Environmental Policy Act. This has not been done, however, because the Department of Interior concluded in 1983 that ESA listings do not legally require the preparation of EIS documents. This is unfortunate because this listing action, if implemented, has the potential to significantly impact ASRC and its shareholders. The potential for a negative impact on the local community from an ESA listing has been seen in other ESA listings such as the spotted owl and various salmon listings in the Pacific Northwest. The potential negative impacts from listing the polar bear under the ESA could affect:

- the thousands of Inupiat Eskimo people who live in Villages and communities on Alaska's North Slope;
- local community needs for infrastructure by imposing increased costs and permitting delays for Villages and their local government in their efforts to provide essential public services for their residents;
- the flow of tax revenues to the North Slope Borough and the State of Alaska which support our schools and many other basic public services;
- our people's subsistence taking of wildlife species in the North Slope's marine and onshore environments;
- the continued and expanded exploration and production of needed domestic oil reserves on the North Slope and their costs; and
- the viability and timing of the proposed Alaska natural gas pipeline which, if constructed, would deliver large volumes of needed gas reserves to United States consumers.

Preparation of an EIS would go a long way towards providing information on the many socio-economic issues and questions presented. An EIS would include a review of all available and reasonable alternatives to the proposed polar bear listing, thus determining the most constructive way to benefit the polar bear population. Further, for USFWS, moving more deliberately and preparing an EIS would permit a better evaluation of the applicable science, the root causes of the problems presented, an analysis of available remedies, a determination of the costs of unintended socio-economic impacts and generally lead to a more informed policy decision.

2. Impact of the Listing on all Alaska Natives

USFWS should be aware that the proposed listing of the polar bear, if implemented, may have significant impacts on ASRC and on the eleven other Alaska Native Regional Corporations (ANC's) in Alaska and their shareholders, most of whom are located <u>outside</u> the range of the polar bear. This is because under the provisions of Section 7(i) of Alaska Native Claims Settlement Act of 1971 (ANCSA), all ANC's are required to share 70 percent of the revenues derived from their lands with each of the other eleven ANC's. ASRC is a major provider of 7(i) revenues. If revenues to ASRC decline because of an ESA listing (e.g., new regulatory requirements, delays in permitting, restrictions on oil and gas developments or for other related reasons), this will reduce the level of 7(i) payments. We understand that such economic concerns are not a factor in USFWS's decision to list a species under the ESA. However, economics are a factor in the designation of critical habitat for a listed species and decisions to limit or curtail activities in areas designated as critical habitat.

3. ASRC's Recommendation on the Proposed Rule

Based upon our review of the proposed rule, ASRC recommends that USFWS should withdraw the proposed listing of the polar bear as threatened under the ESA as the evidence presented does not justify such a listing. The proposed listing does not meet the ESA's prescribed criteria because: 1) the available scientific data does not support the conclusion that polar bear populations are declining; 2) traditional Eskimo knowledge does not support the conclusion that polar bear are negatively impacted by "Arctic warming" or that polar bear populations are declining; 3) assuming that global climate change causes sea ice in the Arctic to recede, the immediate and foreseeable impacts of receding sea ice on polar bears is not likely to cause the species to be threatened with extinction; and 4) even if receding sea ice has some negative impacts on the polar bear, there are sufficient existing regulatory mechanisms to prevent the species from being threatened with extinction.

As noted further in our comments, USFWS has an obligation to consult with the Alaska Native Villages represented by ASRC regarding development of the rule to list polar bear under the ESA and with ASRC regarding management of the polar bear, a subsistence species. We look forward to the fulfillment of this consultation requirement, and an opportunity to discuss with USFWS the comments set forth below.

Sincerely,

V.P. Lands

For Roberta Quintavell
President and Chief Executive Officer for
ASRC

Comments of Arctic Slope Regional Corporation on the Proposed Rule to List the Polar Bear (*Ursus maritimus*) as Threatened Throughout Its Range

I. INTRODUCTION

Thank you for affording Arctic Slope Regional Corporation (ASRC) the opportunity to comment on the United States Fish and Wildlife Service's (USFWS) proposed rule to list the polar bear (*Ursus maritimus*) as threatened throughout its range under the Endangered Species Act (ESA).[1] 72 Fed. Reg. 1064 (January 9, 2007). For thousands of years, the Inupiat people have lived off the Arctic Ocean and on lands within the North Slope of Alaska. Inupiat culture, society and economy have coexisted with the polar bear. Because of our special relationship with the polar bear, ASRC and its Inupiat shareholders have a unique interest in this ESA listing decision.

ASRC has an obligation to protect our Inupiat shareholders' interests by ensuring that USFWS's proposed rule is objective, based on good science, draws on all relevant scientific disciplines and is informed by—and respects—Inupiat traditional knowledge of our environment, including the use of sea ice[2] by polar bears. In our view, the proposed rule to list the polar bear falls short.

Based upon our review of the proposed rule, the listing of polar bears as threatened under the ESA is not warranted at this time because: 1) the available scientific data do not support the

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1 Richard Glenn, Vice-President of Lands for ASRC, has been authorized to coordinate ASRC's comments regarding USFWS's proposed rule. Mr. Glenn testified before USFWS at the March 7, 2007 hearing in Barrow, Alaska (testimony attached as Appendix A). Points made in Mr. Glenn's testimony have been endorsed by ASRC and incorporated within this comment document.

2 In the proposed rule, USFWS uses the generic term "sea ice" when discussing the polar bears' habitat. As noted in these comments, there are several different types of sea ice which are used by the polar bear, for example, landfast ice (or fast ice), marginal ice, or perennial ice pack. The different types of sea ice have different characteristics which should be noted by USFWS. For purposes of our comments, landfast ice means sea ice that is immobile due to its attachment to a coast, usually extending offshore to about the 20-m isobath; marginal ice (or the marginal ice zone) is delimited by the influence of low density meltwater and scattered ice flows from the receding pack ice and by the penetration of ocean swell into the pack ice; and perennial ice pack includes sea ice that is capable of substantial motion and deformation. It is inaccurate for the agency to refer solely to "sea ice" in discussing polar bear habitat in the Arctic.

conclusion that polar bear populations are declining; 2) traditional Eskimo knowledge does not support the conclusion that polar bear are negatively impacted by "Arctic warming" or that polar bear populations are declining; 3) assuming that global climate change causes sea ice in the Arctic to recede, the immediate and foreseeable impacts of receding sea ice on polar bears is not likely to cause the species to be threatened with extinction; and 4) even if receding sea ice negatively impacts the polar bear, there are sufficient existing regulatory mechanisms to prevent the species from being threatened with extinction.

The polar bear is, of course, an iconic species of the United States, if not of all nations. Making the charismatic polar bear a "poster child" in the national and international climate change debates—without demonstrating that climate change *is in fact* adversely impacting polar bear populations—does not serve the interest of the polar bear, the ESA or the United States.

II. BACKGROUND

A. ASRC and its Inupiat Shareholders

ASRC is a private, for profit, Alaska Native owned corporation created at the direction of Congress under the terms of the Alaska Native Claims Settlement Act of 1971 (ANCSA). ASRC represents the interests of its more than 9,000 Inupiat shareholders. ASRC is committed to preserving the Inupiat subsistence way of life, culture and traditions that strengthen both our shareholders and ASRC. Adhering to the traditional values of protecting the land, the environment, the wildlife and the culture of the Inupiat is the foundation of ASRC's mission. ASRC represents eight villages on the North Slope of Alaska: Point Hope, Point Lay, Wainwright, Atqasuk, Barrow, Nuiqsut, Kaktovik and Anaktuvuk Pass. As a corporation, ASRC employs 6,000 people and has a growing shareholder population. ASRC was granted, and holds legal title to, approximately five and a half million acres of the 56 million acres of land on

Alaska's North Slope which the Inupiat people used and claimed under aboriginal title. ASRC's subsidiaries offer companies doing business on Alaska's North Slope engineering, consulting services, civil construction and oil and gas field support services. ASRC is also engaged in petroleum refining and distribution, aerospace engineering services, communications, venture capital management and facilities management services.

B. Traditional Knowledge

There is no other group in the country with as much historical knowledge on the polar bear and its habitat as our Inupiat shareholders. Our knowledge is both traditional and, in some cases, scientific as many Inupiat people are involved in conducting and supporting scientific research on wildlife, sea ice conditions and climate change. Fundamentally though, our knowledge is traditional and built upon thousands of years of experience with the polar bear and its habitat.

C. Shared Concerns

The Inupiat people in general are just as concerned as members of the American public, perhaps even more so, about the changes in sea ice conditions over time and the potential impact of these changes on polar bear and other wildlife species in the Arctic. We monitor these changes closely because they are critical to our subsistence way of life and our culture. The Mayor of the North Slope Borough spoke eloquently on this point in his remarks at the hearings in Barrow, Alaska on March 7, 2007. We ask that those remarks be accorded careful attention by USFWS.

D. ASRC's Inupiat Shareholders and Our History

ASRC represents both the individual Inupiat and their cultural and traditional interest in the polar bear and its corporate interest as a major landholder and provider of services to companies involved in North Slope oil and gas exploration, development and production. The officers of ASRC, acting pursuant to our Board's policy decisions, have an obligation to present our judgment on state and federal issues which impact ASRC's business interests and our shareholders' cultural and traditional interests.[3]

The Inupiat people have a unique standing on this proposed rule. We have lived for thousands of years as the only residents of the American Arctic in a difficult environment that demanded pragmatic study and understanding of all Arctic wildlife species, including the polar bear. Much of our early interaction with the outside world has had negative aspects: exploitation by early commercial whalers; the introduction of diseases, alcohol and drugs; the taking of 50 million acres of our lands by the federal government for the State of Alaska and for mineral, oil and gas development; and the past subversion of our culture, language and traditions by government agencies. Our concerns about change in the Arctic and our lives are well grounded in our historical experiences. ASRC respectfully requests that USFWS consult directly with officials at ASRC and other North Slope native entities to address our concerns before proceeding further in this matter.

E. Basis for Addressing ASRC's Concerns

ASRC has many direct interests in USFWS's proposed rule to list the polar bear as a threatened species under the ESA and significant concerns about the science and other related matters advanced to justify the proposed rule. USFWS should spend additional time and resources to focus on these issues and concerns. As noted in Executive Order 13175 (April 29, 1994), USFWS has an obligation to communicate on a government-to-government basis with the Alaska Native entities recognized by the Secretary of Interior. The eight Villages represented by

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[3] ASRC respects the views of all our shareholders and has encouraged local Village leaders to present their individual views to USFWS on this important matter. To this end, ASRC has made an effort to bring USFWS's proposed polar bear listing to the attention of local Village leaders.

ASRC are included on the Secretary of Interior's list of Indian Entities Recognized and Eligible to Receive Services from the United States Bureau of Indian Affairs and should be afforded the consultation benefits described in Executive Order 13175. We ask that USFWS fulfill its requirement to have regular and meaningful consultation and collaboration with officials in the development of this federal action that will have substantial implications for the Villages.

III. COMMENTS

A. Issues with the Scientific Studies and Data

1. The proposed listing's documentation and study of polar bear population levels and trends do not support a listing at this time.

The polar bear species is comprised of 19 relatively discrete populations located in the Arctic's vast expanse, with populations in several different countries including the United States, Canada, Greenland, Norway and Russia. The proposed rule notes both the status and a trend assessment for each polar bear population. 72 Fed. Reg. at 1070. The current population numbers used in the proposed rule indicate that, of the 19 world-wide population projections analyzed, two-thirds are described as not determinable or not declining. Of the 19 populations, the status of seven populations cannot be determined, six populations are "not reduced", four populations are "reduced" and two populations are identified as "severely reduced from prior excessive harvest". 72 Fed. Reg. at 1070.

With respect to the predicted population trend, the proposed rule states that for seven populations the trend cannot be determined, for five populations the trend is stable, for five populations the trend is declining, and for two populations the trend is increasing. 72 Fed. Reg. at 1070. ASRC appreciates the effort being made, particularly over the past decade, by dedicated scientists to establish a solid count of polar bears. However, the population data and projected trends included in the proposed rule do not support a listing at this time. The data do, however, indicate that more intensive polar bear population research and study should become a priority.

ASRC is familiar with the case of the Southern Beaufort Sea population (the population with the most extensive data and life history), which the proposed rule states has a "predicted trend [of] declining and the status is designated as reduced". 72 Fed. Reg. at 1070. Yet in another portion of the proposed rule the current population numbers for the Southern Beaufort Sea population are described as "not statistically different" than previous population counts of prior decades. 72 Fed. Reg. at 1076. These statements on the Southern Beaufort Sea population are inconsistent. It appears that USFWS determined that the population's trend is declining due to a study showing a variation in survival rates, weights and skull sizes for cubs and not based on a decline in the numerical population. 72 Fed. Reg. at 1076. Based on information presented in the proposed rule, it is not reasonable for the agency to project that the population will decline or that the population status is reduced given that the current population is consistent with population counts of past decades.

USFWS's data regarding the number of animals in a discrete polar bear population has other significant gaps which may result in an under-reporting of the animals comprising a polar bear population. For example, the population number for the Chukchi Sea population is estimated to be 2,000 based "on extrapolation of aerial den surveys". 72 Fed. Reg. at 1070. USFWS acknowledges that the status and trend for this population cannot be determined based on existing data. However, we question whether even the 2,000 population number should be used because it is based on aerial den surveys, which are not sufficiently reliable to provide an accurate population count. This type of population estimate is insufficient to support a listing under the ESA.

The data on the number of animals comprising a polar bear population also does not appear to have taken into account migrating animals within a population. Polar bears migrate and are in flux between locations. Scientists and Alaska Natives have documented polar bear denning on the pack ice in the central Beaufort Sea; those dens subsequently have drifted with the pack ice. This observation is significant because in the Arctic, as noted in the proposed listing, polar bears denning on pack ice may travel with the ice outside their usual locations. As described by Mr. Glenn in his testimony in Barrow, Alaska on March 7, 2007 (*see* Appendix A), in the span of several months a den drifted from the central Beaufort Sea to the Wrangell Island vicinity, offshore of the Russian Far East. The mother and cub emerged from the den there and traveled back to the Beaufort Sea area. This shows that dens can drift, and polar bear from one population may exist in different areas of the Arctic. In this instance, the mother and cub traveled through approximately three different polar bear populations' areas in the space of a few seasons. By not taking into account migrating polar bears, a population's numbers are likely to have been under-reported by USFWS in the proposed rule. The accuracy of current population counts is a threshold issue in an ESA listing, and should be determined with a greater degree of certainty than that exhibited in the proposed rule.

Also, the data on polar bear populations' levels and trends in the proposed rule were largely extrapolated from cursory data and not derived from focused, in-depth studies. Rather than relying upon peer-reviewed studies and data to determine the potential effects of climate change on polar bear populations' levels and trends, USFWS relied upon projections and modeling. Even the authors of key studies relied upon by USFWS have described a "high degree of uncertainty" in the use of projections to determine the impact of climate change on polar bear populations' levels and trends. Derocher et al. 2004, p. 173. USFWS's decision to base the proposed listing on data with a "high degree of uncertainty" is not consistent with the level of scientific information required to support a listing under the ESA.

Finally, the proposed listing is based primarily on climate change and the loss of sea ice habitat, not a statistical decline in polar bear populations' numbers. In the proposed rule, USFWS focused more on the data provided by projections of climate change impacts on sea ice than on the current numerical status of the polar bear. Without a clear understanding of the number of animals comprising each polar bear population, how can USFWS determine whether or not the polar bear population levels are declining? Projections and modeling provide a "high degree of uncertainty" and should not be the basis for a determination that polar bear populations will exhibit declines in the future. There is too much uncertainty in the proposed rule regarding the current number of animals within each of the 19 polar bear populations and the lack of peer-reviewed scientific studies and data regarding polar bear populations levels and trends to support a listing of the entire species at this time.

2. *The proposed listing lacks sufficient documentation and study of the impact of sea ice conditions and climate change on polar bear population levels and trends.*

USFWS found that the current and anticipated changes to the polar bear's sea ice habitat will result in decline of polar bear populations' levels significant enough to warrant listing for the entire species under the ESA. However, the studies cited by USFWS in the proposed listing are hesitant to predict future polar bear population trends. The 2004 Derocher study, which is cited throughout the proposed rule, states: "[i]t is not possible to confidently predict whether a reduction in sea ice area would necessarily result in a corresponding reduction in the size of polar bear populations . . . in some areas polar bear populations may increase if the changes [result in] increased seal populations." Derocher et al. 2004, p. 171. The report also concludes that there is a "high degree of uncertainty" about many of its own predictions. Derocher et al. 2004, p. 173.

The proposed rule hypothesizes that a potential decline in abundance and distribution of ringed seal, considered by USFWS as the primary prey of the polar bear, due to changes in the sea ice habitat would cause a corresponding decline in the polar bear populations' levels. 72 Fed. Reg. at 1074-75. Yet the data used by USFWS is insufficient to support this key conclusion. The agency's conclusions regarding the potential impacts of projected sea ice changes on ringed seals are speculative. The proposed rule contains no data showing a population decline of ringed seal populations in the Arctic, despite the current reduced summer ice conditions. Without supporting data, the proposed rule concludes that a "reduction in sea ice is likely to result in a net reduction in abundance of ringed seals", citing only one study, ACIA 2005, at p. 520. In the absence of reduced or declining ringed seal population numbers—at a time when the summer sea ice is receding, it is not reasonable for USFWS to conclude that changes in sea ice (due to global climate change) will cause ringed seal abundance and distribution to decline, thereby significantly affecting the polar bear populations' levels leading to a threat of extinction.

3. The proposed listing lacks adequate review of existing studies and data on climate change and the causes of sea ice recession in the Arctic.

USFWS's proposed rule references scientific studies and data written by a relatively small group of polar bear researchers and scientists, and does not reflect the views of the larger scientific community which has studied the Arctic and the potential impacts of global climate change on that environment. While there is a consensus among researchers and scientists about warming in the Arctic, there is little scientific consensus as to the causes of this condition, how long this warming trend will continue, and its long-term impacts on the polar bear. USFWS has determined that the warming trend is caused by climate change— primarily human actions creating CO_2—and the greenhouse effect. The agency then concludes that the impact of climate change has resulted in a receding of sea ice, threatening the habitat of polar bear and necessitating a listing of the species under the ESA. 72 Fed. Reg. at 1094. However, USFWS's proposed rule does not acknowledge, much less address, the lack of consensus among the scientific community regarding the relative causes for warming in the Arctic. The agency's failure to review *existing* scientific studies on warming in the Arctic, climate change and the impact on sea ice which conflict with the view set forth in the proposed listing is a significant shortcoming in the proposed listing.

a. *Questions about Science and the Understanding of Climate Change in the Arctic*

USFWS determined that global climate change was causing habitat modification in the Arctic, endangering the polar bear populations. 72 Fed. Reg. at 1095. However, the proposed rule failed to address several issues related to the impact of climate change in the Arctic and the impact such a change would have on the polar bear. The following issues should be addressed by USFWS before finalizing the proposed rule:

- Are the climate changes in the Arctic natural and are the climate changes cyclical and transitory?
- How long will warming in the Arctic occur before the trend flattens or reverses?
- Have polar bears experienced similar climate changes in prior Arctic history[4]?

[4] In the last 10,000 years, polar bear have survived at least two periods of significant climate warming, including a period when temperatures were much warmer than present. CRS Report 2007, p. 9-10 (available at http://www.opencrs.com/rpts/RL33941_20070327.pdf>). During this time, the sea ice above North America retracted substantially allowing Arctic species to reach areas they cannot reach today. CRS Report 2007 at p. 9. While USFWS mentions historic warming periods in the proposed rule, the agency has not provided a detailed examination of the climate record for the Arctic. *See* 72 Fed. Reg. at 1081. By not reviewing the climate change record and the ability of polar bear to survive similar (if not more sever) periods of climate warming, USFWS has

- Can polar bears adapt to climate changes and have they successfully adapted to such changes in the past (e.g., in previous ice ages and other more recent cooling trends followed by warming trends)?
- What are other likely contributory causes of observed changes in nearshore ice recession? To what extent are changes to nearshore ice caused by the introduction of greenhouse gases (CO_2) in the atmosphere, and to what extent do the changes to nearshore ice reflect a normal cycle of warming after what some scientists refer to as the recent "Little Ice Age" of 1500 to 1800?
- Does USFWS have sufficient understanding of climate change history in the Arctic to conclude that the sea ice changes which are currently occurring actually "threaten" the polar bear populations?

The answers to these questions are vital to provide a supportive record for the proposed polar bear listing, and to support additional management and regulatory initiatives for conservation of the polar bear.

b. Studies Regarding Global Climate Change and the Arctic

i. Study of the Impact of "Natural" Warming in the Arctic

Dr. Syun-Ichi Akasofu, a leading and long-time Arctic scientific researcher and Founding Director of the International Arctic Research Center, has recently published a recent paper which focuses on the causes of warming in the Arctic.[5] USFWS stated that a significant factor in the listing of the polar bear is the threat of habitat loss due to sea ice recession caused by climate change. Dr. Akasofu's paper reviews the current warming trend in the Arctic and whether or not

created a gap in the scientific data for the proposed listing, and failed to consider the "best scientific and commercial data available."

[5] Dr. Akasofu, "Is the Earth Still Recovering from the 'Little Ice Age'?" (2007) available at <http://www.iarc.uaf.edu/highlights/2007/akasofu_3_07/Earth_recovering_from_LIA.pdf> (attached as Appendix B).

such a warming trend has a historical basis. Dr. Akasofu concludes that the majority of warming in the Arctic—two-thirds—is the result of "natural" warming, and a third of the warming can be traced to CO_2 and greenhouse gas climate change caused by human activity. USFWS should review this and other studies and data which specifically review the impact of climate change in the Arctic, because a final decision on the proposed rule is driven by the effect of global climate change on polar bear habitat. Dr. Akasofu is a respected scientist who has an understanding of the Arctic and has specifically looked at the warming of the Arctic and potential causes. USFWS should review studies such as Dr. Akasofu's which look at the various potential causes of warming in the Arctic.

ii. Study on the Impact of Advection on Sea Ice

In reviewing the forces leading to a loss of sea ice in the Arctic, USFWS should include studies that explore whether the reduction in sea ice is due in part to a combination of the ice pack melting and advection (ice leaving the Arctic via the Greenland Strait (between Greenland and Iceland). As noted in an article by Walter B. Tucker III et al, "[w]hen the [North Atlantic Oscillation] index is strongly positive, as in the 1990s, a weakened or non-existent Arctic anticyclone suppresses the Beaufort Gyre. This regime causes ice to be advected rapidly out of the western Arctic, which, along with increased melting, inhibits the development, accumulation, or incorporation of large amounts of thicker deformed ice."[6] The reduction in sea ice due to advection is not likely to be permanent, although it may take many years to increase the thickness of the ice. The study found that "a shift back to the anticyclonic circulation pattern (Proshutinsky and Johnson, 1997) would again increase ice thickness in the western Arctic, although a number of years may be required to substantially increase thickness." *Id.* As required

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6 Walter B. Tucker III et al, "Evidence for rapid thinning of sea ice in the western Arctic Ocean at the end of the 1980s", Geophysical Research Letters, Vol. 28, No. 14, 2851, at 2854 (July 15, 2001).

by the ESA, USFWS should review the "best scientific and commercial data available" and the study of advection and its impact on sea ice in the Arctic would fit that designation, particularly since the reduction of sea ice is cited as the main reason for the proposed listing of polar bear.

B. Use of Traditional Knowledge in the Proposed Listing

1. Traditional knowledge indicates that a marginal ice zone does not negatively impact polar bear.

A significant factor in USFWS's decision to list the polar bear was thc impact of the receding perennial ice pack and the agency's determination that this equates to a "habitat loss". 72 Fed. Reg. at 1095. USFWS also mentions increased fetches of open water, and its negative effects on denning and feeding. 72 Fed. Reg. at 1075-76. There is little mention of the marginal ice zone which must, and does, grow at the expense of a receding perennial ice pack. It is in this marginal ice zone that Inupiat subsistence hunters consistently see polar bears efficiently hunting ringed and bearded seals and walrus in the summer months.

In waters offshore of ASRC's coastal villages, from mid-July to mid-August, Inupiat people observe polar bears hunting in the marginal ice zone. This coincides with the arrival of the walrus herds, ringed seals and bearded seals on and around drifting ice floes. This is an important habitat in which polar bears thrive because they can catch napping prey on ice floes, or use the floes for cover to catch animals in the water. As noted in Appendix A, blood-stained ice and feeding remnants on the drifting floes are numerous at this time of year.

Derocher, whose 2004 study is frequently quoted by USFWS, notes that "if the multiyear ice . . . is largely replaced by annual ice . . . and the polynyas in the area [become] more numerous and larger it is likely that biological productivity might increase . . . and the area would become better habitat for polar bears." Derocher et al. 2004, p. 169 (emphasis added). USFWS's proposed rule fixates on the "pack ice" as essential polar bear habitat but does not adequately explore or acknowledge the extensive use of the marginal ice zone by polar bear. USFWS's lack of study and focus on this significant polar bear habitat is a major omission, which should be reconsidered before proceeding with the proposed listing.

2. *Eskimo/Inupiat observations conflict with information supplied by USFWS in the proposed rule.*

As detailed below, the Inupiat people have many observations, experiences and traditional knowledge which are at odds with statements put forth by USFWS in the proposed rule. We ask that USFWS work with ASRC and other Inupiat institutions to clarify and resolve these differences before making a final decision on the proposed rule.

a. *Observations from Polar Bear Hunting*

In the proposed rule, USFWS downplays the use of the marginal ice zone by polar bear as part of the species habitat. It is our experience that polar bears frequent the marginal ice zone due to the hunting opportunities. Our hunters have seen polar bears come closer to shore in late spring from mid-May to early June when the ringed seals give birth to pups beneath stable snowdrifts on landfast sea ice. The polar bears smell the odor of a den of newborns seal pups beneath snowdrifts. Appendix A notes Inupiat observations made while following bear tracks in the spring and watching how and where the polar bear hunt the seal pups. Inupiat hunters and others have also accompanied scientists and trained dogs to the seal dens, which are not visible from the surface, but which have an odor that polar bears, foxes, and these trained dogs can detect.

b. *Instances of Polar Bear Cannibalism*

In the proposed rule, USFWS emphasizes that three instances of polar bear cannibalism were observed in 2004, leading to the conclusion that the interaction of environmental factors and nutritional stress are causing unusual behavioral events. 72 Fed. Reg. at 1076. However, the

Inupiat have observed and been taught by Elders and by traditional knowledge that a male polar bear will eat anything—including a female bear or cub—even when alternative food sources exist. This behavior cannot be ascribed to starvation when it is part of the polar bears' intrinsic character.

c. Polar Bear Use of Terrestrial Habitat

The proposed rule concludes that reductions in sea ice have forced polar bears to utilize terrestrial habitat which contributes to nutritional stress. 72 Fed. Reg. at 1073-74. However, the Inupiat people who live along the Arctic coastline have observed this behavior for many years. Some polar bears will stay on the coast in the summer months, not necessarily because they are trapped there by the absence of ice, but because that is the season for them to feed on dead grey whales that the waves have brought ashore, or on beached walrus pups, or seals basking on the beach. The Inupiat who live along the Arctic coastline see this every year along the Alaskan coast; and it has also been documented at Wrangel Island. *Contra* 72 Fed. Reg. at 1073.

d. Polar Bears as Scavengers

In September to October, polar bears feed on the remains of gray whales, walrus and other dead animals that have washed ashore during the fall-time storms. Groups of polar bears have been seen by our villagers establishing an over-wintering circle around any large carcass, such as a grey whale, that can sustain them through the winter. In the fall-time, polar bears also prey on walrus and seals that are resting on the beach. The bears also feed on the remains of bowhead whales harvested by fall-time whale hunters of the three eastern North Slope villages. While much has been written about the presence of polar bears around bowhead whale remains, traditional knowledge indicates this is simply a part of their natural feeding cycle. There are many naturally occurring carcasses that wash ashore that would sustain the polar bears in the absence of the bowhead whale remains created by subsistence hunting. The proposed rule largely ignores these natural food sources of the polar bear without affording them appropriate consideration. These sources of food deserve further consideration, particularly in light of USFWS's uncertainty regarding the potential decline of ringed seals population and/or ringed seal availability as prey to polar bears.

e. Alternative Polar Bear Habitat

None of the hunting environments described above are on the multi-year "ice pack", but instead are located in the "marginal ice zones" and nearshore lands of the Beaufort and Chukchi Sea. This conflicts with USFWS's findings that sea ice is an essential platform from which polar bears meet life functions. 72 Fed. Reg. at 1080. The proposed rule also describes sea ice as "primary" polar bear habitat, but provides an insufficient analysis of these alternative habitats in which the Inupiat consistently observe polar bear. 72 Fed. Reg. at 1067. Alternative habitat for polar bear requires further analysis, particularly for a highly adaptive species such as polar bear, when that species is undergoing a potential change in habitat. 72 Fed. Reg. at 1066. The proposed rule should not ignore the existing, non-pack ice habitat of polar bear. As noted in Appendix A, the polar bear is an opportunistic animal and will eat whatever it can find. Polar bear have been known to be more than sixty miles inland, even with ice conditions that would have readily allowed them offshore perennial ice pack without swimming great distances. Polar bear hunt seals, belugas, and walrus from breathing holes, and leads in both the pack ice and marginal ice zones. A polar bear is at home in the water, on the ice, and on the land. Polar bears adapt to the environment at hand and are not limited to the perennial ice pack as habitat.

Inupiat hunters, using traditional knowledge and observation, know that a polar bear can swim better than it can walk—it is definitely a marine mammal. Although there must be a finite distance for the polar bear's swimming range, it is considerable. In the proposed rule, USFWS concluded that a recent incident involving the drowning of polar bears is an indication of the harmful impacts of climate change and sea ice regression. 72 Fed. Reg. at 1077. However, USFWS provided no information that the instance of polar bear drowning is a recent phenomenon. Because the incident was recently observed does not mean that the event is unique or a recent development. Polar bears have adapted in the past, and adapt over time to changing habitat, prey and other food sources. There are changing and varied cycles of habitat, ice environment, prey animals and food sources for the polar bear in our region, including marginal ice zones, shorelines, inland areas, leads and multi-year ice.

3. ASRC officials, Elders and other Inupiat Shareholders' observations and traditional knowledge of the polar bear do not support a polar bear listing under the ESA at this time.

ASRC has made the Federal Register proposed rule available to elected officials, Elders and other ASRC shareholders who live in our North Slope Villages together with the testimony of the North Slope Borough Mayor Itta, Richard Glenn and others at the March 7, 2007 hearing in Barrow. A summary of some of the observations and the traditional knowledge of the Inupiat people who live in our Villages on this proposed listing of the polar bear as threatened are set forth below.

Our North Slope village residents would support greater conservation protection for the polar bear if a case were made that the polar bear and its habitat are threatened by any conditions that the Inupiat people, or our units of government, can act to control. Observation over decades by Village people, however, identifies no such specific conditions threatening the polar bear that can be addressed by either USFWS or our people. Indeed, our people see and interact with more polar bears in recent years than they did 10, 20 or even 40 years ago, indicating that existing conservation regulations for polar bear at the local, state, federal and international levels are working well. The species is healthy and overall the populations appear to be relatively stable.

Our Village people agree that we are seeing warming in the Arctic. Many of our Elders say, however, that this change is part of a normal and re-occurring cycle. Every year, and every generation, our weather is different; sometimes warmer, sometimes colder. Weather and ice conditions in the Arctic change annually and over the decades. Our Elders say these changes are cyclical over the generations. The Inupiat people have adapted to these changes over hundreds of years. So have the Arctic's wildlife species, including the polar bear. Our traditional knowledge tells us that environmental change is constant and dynamic in the Arctic, much more than in other climatic regions. That the Arctic warming is a natural, cyclical climate change should be fully considered by USFWS.

4. The proposed listing of polar bear is similar to the attempt to list the bowhead whale in the 1970's, in which the Inupiat demonstrated by traditional Native knowledge and science that the whale was not endangered.

Our Inupiat leaders say that this proposed listing of the polar bear reminds them of the efforts in the early 1970's to declare the bowhead whale as an "endangered species." This led to a major effort to prohibit the Inupiat people's traditional subsistence whale hunts. The Inupiat people went to court, initiated scientific studies, conducted population counts and eventually won this debate. With the assistance of hard work, traditional Native knowledge and good science, the Inupiat proved that the bowhead whale species was, in fact, growing, not declining. As a result, we were able to save our whaling tradition, our Inupiat culture and our traditional subsistence way of life. This important lesson from the history of international and national government agencies acting on the basis of inadequate study and science should be examined in the context of this proposed polar bear listing.

Based on our bowhead whale experience of the 1970's, the Inupiat people developed and implemented a program of whale conservation and self regulation. Our Whaling Captains' Associations acted to study, monitor, conserve and regulate the Inupiat's traditional taking of the bowhead whale. This program has proven very successful. It has been copied for other species in the Arctic and Alaska as well as by indigenous people in many other parts of the world for the conservation of their wildlife.

One option, not addressed by USFWS in the proposed rule, is that the Inupiat, with our traditional knowledge of the Arctic and our wildlife, should play a larger role in conserving the polar bear. USFWS could begin by employing experienced Eskimo hunters and whalers to observe, study and monitor the polar bear as the Inupiat did for the bowhead whale studies, population counts and assessments in the 1970's. Traditional and common-sense knowledge is, as history shows, very important. USFWS and Department of Interior (DOI) should seek full access to this breadth of knowledge and year-round, first hand traditional knowledge before taking premature action to list the polar bear as threatened.

C. Existing Regulatory Mechanisms in the Proposed Listing[7]

1. *The proposed listing did not adequately consider existing regulatory mechanisms regarding polar bear conservation.*

USFWS has not fully taken into account current available conservation measures for polar bear. One key listing factor in the listing of species under the ESA is the consideration of the "inadequacy of exiting regulatory mechanisms" to conserve the species. 16 U.S.C. § 1533(a)(1)(D). Polar bear conservation is governed by a number of federal and international measures, including: the work of the Alaska Nanuuq Commission, the 1973 Agreement on the Conservation of Polar Bears, the 2000 bilateral Agreement between the Government of the

[7] For additional information on the international, federal, state and local regulatory mechanisms described in Section C. of these comments, see Appendix C.

United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population, the United States-Russia Polar Bear Conservation and Management Act of 2006, the Inuvialuit-Inupiat Polar Bear Management Agreement in the Southern Beaufort Sea and, more generally, the Marine Mammal Protection Act and the Convention on International Trade in Endangered Species of Fauna and Flora. These actions and forums, several of which have recently been strengthened, should be more thoroughly considered by USFWS. The agency should consider in particular the recent changes that were hard-won and international in scope, and use significant indigenous resources to protect the very species that is the focus of the proposed listing. A thorough consideration of these mechanisms is required by law, but such a consideration is not evident in the proposed rule. In their focus on receding sea ice, USFWS has not properly considered existing polar bear conservation mechanisms, which consider both the polar bear as a species and the habitat upon which it is dependent.

In particular, two key mechanisms for polar bear conservation have been recently strengthened. The Inuvialuit-Inupiat Polar Bear Management Agreement in the Southern Beaufort Sea, adopted in 2000, is a major agreement for polar bear conservation among indigenous people of the circumpolar north. The agreement is intended "to maintain a healthy, viable population of polar bears in the southern Beaufort Sea in perpetuity", and includes provisions for habitat conservation, take limits and identification of key research tasks. This agreement has led to a higher degree of international cooperation over the conservation of this important population. Actions authorized under this agreement include habitat protection recommendations (Article VIII, (7) (e)).

Congress has expressly recognized the need for increased polar bear conservation in enacting new conservation measures just this past year in the United States-Russia Polar Bear Conservation and Management Act of 2006. The Act significantly strengthens the mission of the Alaska Nanuuq Commission, focusing on the Alaska-Chukotka polar bear population, and establishes a formal international mechanism for polar bear conservation for this population. Importantly, both of these mechanisms span international borders in three key countries for polar bears, the only three for which polar bear populations from the United States can reasonably travel.

The benefit to conservation of polar bears in Alaska, Canada and Russia found in these regulatory mechanisms have significant value to the conservation of the species. There is little evidence in the proposed listing that the conservation benefit of these newly adopted mechanisms has been adequately considered by USFWS.

2. *The proposed listing did not adequately review existing local, state and international mechanisms designed expressly to reduce human causes of climate change (identified by USFWS as having a significant impacting on sea ice).*

Climate change has been identified by USFWS as a major contributor to changes in sea ice habitat. 72 Fed. Reg. at 1071. There is no evidence that, in the proposed rule, USFWS considered recently adopted or strengthened local, state or international initiatives designed to reduce the man-made causes of climate change which contribute to warming in the Arctic, impacting sea ice, which in turn is cited as the primary factor for the determination that polar bear are a threatened species. 72 Fed. Reg. at 1082. The proposed rule contains incomplete information on existing regulatory systems and mechanisms to address climate change.

a. International Regulatory Mechanisms

The impact of climate change on the Arctic, and conservation of species in the Arctic, has been addressed by a high-level intergovernmental forum, the Arctic Council. Formed to ensure environmental, social and economic sustainable development in the Arctic region, current council members include the United States, Canada, Denmark, Finland, Iceland, Norway, Russia and Sweden. Six Arctic indigenous communities are Permanent Participants on the Council. The Arctic Council has five expert working groups focusing on monitoring, assessing and providing scientific work regarding specific issues in the Arctic. The working groups and the scientific data they produce are a valuable resource and should be consulted by USFWS regarding polar bear and the impact of climate change on habitat in the Arctic.

The proposed rule should also note international climate change policy such as the United Nations Framework Convention on Climate Change (UNFCCC), which regulates greenhouse gas emissions. 189 nations, including the United States, have ratified the UNFCCC, agreeing to the common objective of stabilizing greenhouse gas emissions "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." UNFCCC at Art. 2.

b. Federal Regulatory Mechanisms

While the United States federal government has no existing active climate change policy, there are numerous bills currently pending in Congress that should be noted in the proposed rule. Introduced bills regarding climate change include: the Climate Stewardship and Innovation Act, S. 280; the Global Warming Pollution Reduction Act, S. 309; the Electric Utility Cap-and-Trade Act, S. 317; a draft Bingaman-Specter Bill; the Global Warming Reduction Act Bill, S.485; the Climate Stewardship Act, HR 620; and the Safe Climate Act, HR 1590.

Additionally, on April 2, 2007, the United States Supreme Court decided its first climate change case, *Massachusetts v. EPA,* Case No. 05-1120, in which the court determined that the Environmental Protection Agency (EPA) has the statutory authority under the Clean Air Act to issue a rule regulating greenhouse gas emissions from new motor vehicles. Greenhouse gas emissions are a known contributor to climate change. This indicates the policy of the United States' with respect to addressing the causes of climate change through existing statutes and regulatory mechanisms may be undergoing significant change.

c. State and Local Regulatory Mechanisms

While USFWS was correct in noting that the United States lacks a comprehensive federal climate change policy, it failed to note significant state and local measures which have been adopted to reduce greenhouse gas emissions. The Regional Greenhouse Gas Initiative is an example of multiple states engaging in a state-level emissions cap-and-trade program. Also, the California Legislature has adopted an economy-wide cap on carbon dioxide emissions to reduce the state's greenhouse gas emissions, which rank at 12th-largest in the world, by 25 percent by the year 2020. Several other states have adopted or are considering similar measures to reduce their contribution to global climate pollution, such as Washington and Oregon. In addition, the West Coast Governors have adopted a Western Regional Climate Change Initiative through which Washington, Oregon, California, New Mexico and Arizona will work together on climate protection.

Local governments have adopted climate change regulations as well. While the United States is not party to the Kyoto Protocol, 435 mayors from 50 states representing a total population of over 61 million citizens have agreed to meet or exceed the Kyoto Protocol targets in their own communities, including a 7% reduction from 1990 greenhouse gas emission levels by 2012.

d. The Proposed Rule Should Reflect These Regulatory Mechanisms

USFWS's statement in the proposed rule that "[t]here are no known regulatory mechanisms effectively addressing reductions in sea ice habitat at this time" is disingenuous. 72 Fed. Reg. at 1086. The agency has clearly made a determination in the proposed rule that climate change (Arctic warming) is affecting sea ice, and polar bear populations are being affected by changes in the sea ice habitat. Yet in reviewing the factor on "existing regulatory mechanisms" USFWS ignores the vast amount of international, state and local regulatory mechanisms directly addressing climate change—even those directly addressing climate change in the Arctic. While these regulatory mechanisms may not specifically address "sea ice", because they address climate change (which the agency identifies as a major threat to polar bear) USFWS should review the adequacy of these regulatory mechanisms as required by section 4(b)(1)(A) of the ESA.

D. Consultation with Alaska Native Organizations on Subsistence Activities

Section 10 of the ESA allows Alaska Natives to take any endangered or threatened species if the taking is primarily for subsistence purposes. USFWS retains the ability to prescribe regulations limiting the take of such species by Alaska Natives, but only if such taking "materially and negatively affects" the species at issue. 16 U.S.C. § 1529(e)(4). Before issuing subsistence hunting-limiting regulations, USFWS must provide notice and conduct hearings in the affected judicial districts of Alaska, and must also consult with the Alaska Native organizations (including ASRC). *See* Secretarial Order 3225 (2001). The consultation requirement states that the agency must provide technical, financial and other assistance to the

Alaska Native organizations as is appropriate. Secretarial Order 3225 also provides that Alaska Native organizations have the opportunity to participate in the management of subsistence species that are candidate, proposed or listed species under the ESA. The management includes, but is not limited to: forming recommendations for management actions, plans or regulations; population and harvest monitoring projects; law enforcement activities; education programs; research, design, data collection and use of traditional knowledge; habitat protection programs; and recovery projects. Therefore ASRC requests that USFWS consult with ASRC regarding the management of the polar bear, a subsistence species that is proposed for listing under the ESA.

E. Critical Habitat Designation

In the proposed rule, USFWS did not designate critical habitat for the polar bear, instead stating that a careful assessment of the designation of critical habitat would require additional time and evaluation. 72 Fed. Reg. at 1096. USFWS does, however, specifically requests information regarding critical habitat in comments on the proposed rule. The designation of critical habitat should be "on the basis of the best scientific data available and after taking into consideration the probable economic and other impacts of making such a determination . . . ." 50 C.F.R. § 424.12(a). The request for critical habitat data, during the process for the polar bear ESA listing, creates some difficulty for ASRC. First, as noted in our comments, ASRC does not believe that, based on the data and reasoning set forth in the proposed rule, polar bear should be listed under the ESA or that critical habitat should be designated for the species. Second, economic data may not be used in determining if a species should be listed under the ESA. However, USFWS is required to take into account such data in the designation of critical habitat. Submittal of such data by ASRC in these comments could be seen as improper with regards to the potential ESA listing, thus limiting the utility of our comments on the proposed rule.

Since USFWS requested such information, however, the letter of transmittal to these comments provides an overview of some of the economic impacts the proposed listing and designation of critical habitat would have on both the Inupiat people and the Alaska Native community as a whole. If USFWS finalizes the proposed rule and lists the polar bear under the ESA, then ASRC requests that it be consulted and provided a separate opportunity to comment on critical habitat, including presentation of data on the economic impact of specifying areas in the North Slope as critical habitat. Third, USFWS has not presented any indication of which of the immense areas in the range of the polar bear might be listed as critical habitat. Does the agency expect comments on every area potentially traversed by polar bear? If so, the comment period for this proposed rule is far too short for any meaningful data to be gathered or put in a useable format. If USFWS proceeds to finalize the proposed rule and lists the polar bear, the agency should specify the areas under consideration for critical habitat and provide an opportunity for comment at such time.

F. ASRC's Recommendation regarding the Proposed Rule

ASRC proposes that DOI and USFWS withdraw the proposed rule to list the polar bear as threatened. DOI and USFWS should conduct further research on polar bear and prey population data and on the potential effects of sea ice change on the polar bear. In addition, the DOI and USFWS should work with existing regulatory mechanisms to strengthen polar bear conservation. This action would bring needed focus and practical experience to protect the polar bear while expanding our understanding of the polar bear populations and their habitat. It would also mean that the effort for a factual and science based evaluation is now beginning and not concluding. This would create momentum for new studies and research initiatives supported by local governments, the State of Alaska, federal agencies, and international organizations.

This greater emphasis on polar bear conservation and study that ASRC proposes acknowledges that polar bear populations' statistics are uncertain and require additional study, and addresses the need for research on receding ice conditions and the impact of climate change in the Arctic. This action by DOI and USFWS will also spur needed actions by the other Arctic nations on whom the long term well-being of the polar bear is dependant. There are no more than approximately 3,500 of the world's total of 20,000 to 25,000 polar bears within the United States' claimed territory and subject to the United States' jurisdiction. Greater domestic conservation and study by the United States followed by meaningful efforts by the federal government to engage other nations in cooperative evaluations, study and research could—and should—lead to productive bilateral and multilateral efforts to address polar bear conservation and the international problem of climate change in the Arctic. The challenge of dealing with the polar bear's future well-being is very important to the Inupiat people and requires a better understanding of the polar bear populations, their habitat and the causes and effects and the evolving science of climate change as it applies to the unique habitat within the Arctic.

F. Review of the ESA's Five Criteria for Listing a Species

Section 4 of the ESA, and its implementing regulations, prescribe five criteria for USFWS to consider when determining whether to list a species. 16 U.S.C. § 1533(a); 50 C.F.R. § 424.11. Those criteria include: (1) the present or threatened destruction, modification or curtailment of a species habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting the species continued existence. ASRC believes that polar bear do not meet any of the five criteria. As noted above, data do not show that current and anticipated changes to polar bears' sea ice habitat are causing a decline of polar bear populations or pose an increasing risk to polar bear populations. ASRC agrees with USFWS's conclusion that overutilization as a singular factor does not threaten the polar bear. 72 Fed. Reg. at 1085. ASRC also agrees with USFWS that there are no indications that disease or cannibalism will have an effect on the population levels of the polar bear. 72 Fed. Reg. at 1086. ASRC agrees with USFWS that threats to polar bear from direct take, disturbance by humans and incidental or harassment take are adequately addressed through range state laws, statutes and other regulatory mechanisms. 72 Fed. Reg. at 1091. As discussed above, ASRC believes USFWS failed to consider existing regulatory mechanisms at the international, state and local level that address the impact of climate change on the Arctic and the polar bear's habitat. Finally, ASRC agrees with USFWS's conclusion that natural or manmade factors, specifically contaminants, ecotourism and shipping, do not threaten the existence of the polar bear. 72 Fed. Reg. at 1094.

IV. CONCLUSION

ASRC strongly believes that a threatened listing for the polar bears does not meet scientific, legal or regulatory requirements and, ultimately, would have very little impact on the polar bears well-being. It will not create more ice cover. It will not change the polar bear's ability to locate dens or prey. But a listing under the ESA will negatively and disproportionately affect the lives of the people, the Inupiat Eskimos, who co-exist with the polar bear in the Alaskan Arctic. Our communities will run the risk of becoming "critical habitat". Playgrounds, gravel pits, airstrips, landfills, campsites, hunting areas, village expansions—all of these may be limited by the subjective process invoked prematurely and unfairly in the name of the ESA. ASRC instead recommends that we work together to understand the polar bear and its habitat, and specifically work toward understanding the consequences of how development and greenhouse gas emissions generated far away from our lands and waters affect the habitat we share with the polar bear.

APPENDIX A

Microsatellite DNA and mitochondrial DNA variation in polar bears (*Ursus maritimus*) from the Beaufort and Chukchi seas, Alaska

M.A. Cronin, S.C. Amstrup, and K.T. Scribner

Abstract: Radiotelemetry data have shown that polar bears (*Ursus maritimus* Phipps, 1774) occur in separate subpopulations in the Chukchi Sea and the southern Beaufort Sea. However, segregation is not absolute, and there is overlap of ranges of animals in each subpopulation. We used genetic variation at eight microsatellite DNA loci and mitochondrial DNA (mtDNA) to further assess the degree of spatial structure of polar bears from the Chukchi and southern Beaufort seas. Microsatellite allele frequencies and mtDNA haplotype frequencies of bears from the southern Beaufort and Chukchi seas did not differ significantly. Lack of differentiation at both maternally inherited mtDNA and bi-parentally inherited microsatellite loci suggests that gene flow between the two areas is mediated by both sexes. The genetic data indicate that polar bears in the southern Beaufort and Chukchi seas compose one interbreeding population. However, there is considerable fidelity to ranges in each area, particularly by adult females. The combined genetic and movement data suggest that polar bears could be managed as Beaufort Sea and Chukchi Sea subpopulations of a combined southern Beaufort Sea and Chukchi Sea population.

Résumé : Des données de radiotélémétrie montrent que les ours polaires (*Ursus maritimus* Phipps, 1774) de la mer de Chukchi et du sud de la mer de Beaufort forment des sous-populations séparées. La ségrégation n'est pas, cependant, absolue, et il y a un chevauchement d'aires d'animaux de chaque sous-population. Nous utilizons la variation génétique à huit locus microsatellites d'ADN et dans l'ADN mitochondrial (ADNmt) pour préciser le degré de structure spatiale chez les ours polaires de la mer de Chukchi et du sud de la mer de Beaufort. Les fréquences des allèles microsatellites et des haplotypes d'ADNmt chez les ours polaires de la mer de Chukchi et du sud de la mer de Beaufort ne diffèrent pas significativement. Le manque de différenciation tant dans l'ADNmt d'origine maternelle que dans les locus microsatellites hérités des deux parents montre que le flux génétique entre les deux régions est assuré par les deux sexes. Les données génétiques indiquent que les ours polaires du sud de la mer de Beaufort et de la mer de Chukchi forment une seule population reproductive. Il existe, néanmoins, une forte fidélité aux aires vitales dans chaque région, particulièrement chez les femelles adultes. Les données combinées sur la génétique et les déplacements laissent croire que la gestion des ours polaires pourrait bien se faire au niveau des sous-populations de la mer de Beaufort et de la mer de Chukchi au sein d'une population conjointe du sud de la mer de Beaufort et de la mer de Chukchi.

[Traduit par la Rédaction]

Introduction

Polar bears (*Ursus maritimus* Phipps, 1774) in northern Alaska primarily occur in two subpopulations (Fig. 1; Amstrup et al. 2000, 2005). Amstrup et al. (2004, 2005) showed that polar bears occurring between the McKenzie River (Canada) and the Colville River, Alaska, compose a southern Beaufort Sea subpopulation. Similarly, polar bears west of Cape Lisburne, Alaska, represent a Chukchi Sea subpopulation. On an annual basis, more than 90% of the bears in the southern Beaufort Sea subpopulation occur between the Colville River in Alaska and the Mackenzie River in Canada. Similarly, more than 90% of the bears in the Chukchi Sea subpopulation occur west of Cape Lisburne. This high level of fidelity of polar bears to adjacent ranges in the Beaufort and Chukchi seas has led to their management as separate subpopulations, although Amstrup et al. (2005) showed an area of overlap around Barrow (Fig. 1).

Previous analyses suggested there may be some genetic differentiation of bears from the southern Beaufort and Chukchi seas. An analysis of 16 microsatellite loci of 30 bears from each region showed a low level (F_{ST} = 0.01) of differentiation of allele frequencies between the subpopulations in the southern Beaufort and Chukchi seas (Paetkau et al. 1999). An analysis of mitochondrial DNA (mtDNA) restriction fragment length polymorphisms from 10 bears captured in the Chukchi Sea and 15 bears captured in the Beaufort Sea identified three haplotypes, with one predominating (70%–73%) in both areas (Cronin et al. 1991).

These genetic results were preliminary because of small sample sizes compared with the numbers of bears in the

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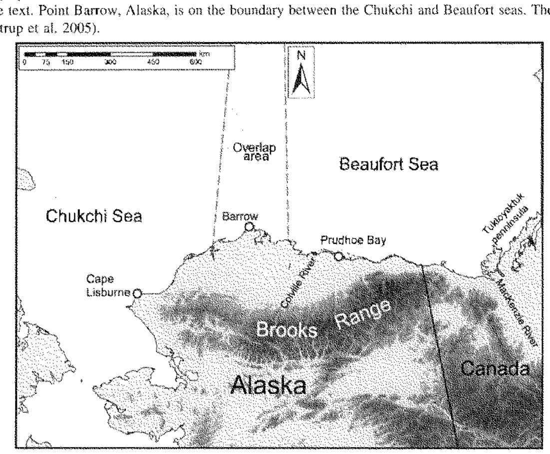
Fig. 1. Map of the geographic area of the southern Beaufort Sea and Chukchi Sea polar bear (*Ursus maritimus*) subpopulations showing place names used in the text. Point Barrow, Alaska, is on the boundary between the Chukchi and Beaufort seas. The subpopulations' area of overlap is shown (Amstrup et al. 2005).



subpopulations. The southern Beaufort Sea subpopulation includes approximately 1800 bears and the Chukchi Sea subpopulation has more than 2000 bears (Lunn et al. 2002). In this paper, we quantify the variations in mtDNA and microsatellite DNA from larger numbers of bears captured in the Chukchi and southern Beaufort seas. mtDNA is maternally inherited and reflects only female-mediated gene flow, while nuclear DNA (e.g., microsatellites) is bi-parentally inherited and provides a measure of gene flow that is mediated by both sexes. Simultaneous analysis of mtDNA and microsatellite DNA provides a more complete picture of the degree of spatial genetic structure than either type of marker alone (Avise 2004). This information is important for an understanding of the population structure of polar bears, and the extent to which movements by both sexes may be reflected in measures of spatial genetic structure. This information may become increasingly useful in conservation and management, as polar bears might face changing habitat conditions coincident with changes in the distribution of sea ice (Stirling and Lunn 1997; Stirling et al. 1999; Ainley et al. 2003; Derocher et al. 2004; Ferguson et al. 2005).

Materials and methods

Blood and tissue samples were collected from bears captured in the southern Beaufort Sea, east of Point Barrow, Alaska, and in the Chukchi Sea, west of Point Barrow, between 1985 and 1995 (Amstrup 2000). Bears were assigned to the southern Beaufort or Chukchi subpopulation depending on the area in which they were captured. We analyzed eight microsatellite loci (*G10C, G10L, G10P, G1A, G10B, G1D, G10X, G10M*) with methods described previously (Paetkau et al. 1995). Microsatellite data consisted of two-allele genotypes for each bear for each locus. We used programs Microsatellite Toolkit (Park 2001) and FSTAT (Goudet 1995) to calculate allele frequencies and measures of genetic diversity, which included observed and expected heterozygosities and allelic richness (El Mousadik and Petit 1996). In all analyses, nominal α levels were adjusted for multiple comparisons among the eight microsatellite loci ($P = 0.006$) using Bonferroni corrections (Rice 1989). We used the GENEPOP program (Raymond and Rousset 1995*a*) to test for Hardy–Weinberg equilibrium and linkage among microsatellite loci. To assess population structure of polar bears sampled from the Chukchi and southern Beaufort seas, we conducted tests of heterogeneity of allele frequencies (Raymond and Rousset 1995*b*) with GENEPOP and calculated interpopulation variance of allele frequencies (F_{ST}; Weir and Cockerham 1984) with program FSTAT. We also used the Bayesian clustering method of Pritchard et al. (2000), implemented in program STRUCTURE to assess spatial structure. The STRUCTURE program uses multi-locus genotypes to infer structure and assign individuals to populations based on posterior probabilities. We examined the probability that polar bears originated from K populations (where K is unknown), for K = 1–4, and where no a priori information of population assignment was used. Posterior probabilities were estimated for all K hypothetical populations. Improvement in goodness of fit for each K population was evaluated using a likelihood-ratio test. Results were based on 1 000 000 Markov chain Monte Carlo iterations following a burn-in period of 100 000 iterations and 2 repetitions of each value of K.

Analyses of mtDNA were as described by Cronin et al. (1991), including isolation of genomic DNA, restriction enzyme digestion, agarose gel electrophoresis, Southern blotting, and hybridization to a radioactively labeled mtDNA

Table 1. Microsatellite allele frequencies, allelic richness (AR), observed heterozygosity (H_o), expected heterozygosity (H_e), and F_{ST} in polar bears (*Ursus maritimus*) captured in the southern Beaufort Sea and Chukchi Sea of northern Alaska, USA. Sample sizes were 116 bears for the Beaufort Sea samples and 127 bears for the Chukchi Sea samples.

Locus and allele	Beaufort Sea	Chukchi Sea
G10C		
101	0.017	0.043
103	0.737	0.732
105	0.194	0.161
107	0.013	0.012
109	0.013	0.035
111	0.009	0
113	0.013	0.012
115	0.004	0.004
AR/H_o/H_e	8.0/0.45/0.42	6.9/0.44/0.44
F_{ST}	–0.001	
G1A		
188	0	0.012
190	0.461	0.465
192	0.103	0.154
194	0.138	0.146
196	0.203	0.157
198	0.047	0.028
200	0.047	0.039
AR/H_o/H_e	6.0/0.73/0.72	7.0/0.78/0.72
F_{ST}	0.000	
G10M		
200	0.065	0.063
206	0.026	0.008
208	0.297	0.272
210	0.289	0.378
212	0.086	0.114
214	0.19	0.142
216	0.043	0.02
218	0.004	0.004
AR/H_o/H_e	8.0/0.73/0.78	7.9/0.74/0.75
F_{ST}	0.004	
G10B		
142	0.164	0.22
150	0.069	0.071
152	0.039	0.051
154	0.461	0.421
156	0.159	0.154
158	0.103	0.083
162	0.004	0
AR/H_o/H_e	7.0/0.72/0.72	6.0/0.72/0.74
F_{ST}	0.000	
G10P		
145	0.478	0.492
147	0.022	0.055
149	0.052	0.035
151	0.043	0.039
153	0.207	0.244
155	0.134	0.114
157	0.034	0.012
159	0.009	0.004
161	0.022	0.004
AR/H_o/H_e	9.0/0.73/0.71	8.4/0.69/0.68
F_{ST}	–0.001	
G1D		
180	0.034	0.008
182	0.552	0.543
184	0.246	0.276
186	0.056	0.083
188	0.047	0.039
190	0.065	0.043
192	0	0.008
AR/H_o/H_e	6.0/0.64/0.63	6.9/0.61/0.62
F_{ST}	–0.002	
G10X		
133	0.125	0.118
135	0.116	0.098
137	0.121	0.075
139	0	0.004
141	0.138	0.169
143	0.362	0.398
145	0.056	0.051
147	0.082	0.087
AR/H_o/H_e	7.0/0.82/0.80	7.9/0.79/0.78
F_{ST}	–0.001	
G10L		
145	0.772	0.768
147	0.147	0.173
149	0.034	0.051
151	0.047	0.008
AR/H_o/H_e	4.0/0.39/0.38	4.0/0.35/0.38
F_{ST}	–0.001	
Over all 8 loci		
AR/H_o/H_e	6.9/0.65/0.64	6.9/0.64/0.64
F_{ST}	–0.0002	

probe. We identified mtDNA haplotypes of polar bears from the Beaufort and Chukchi seas with 2 (*Hin*dIII and *Cla*I) of the 11 restriction enzymes previously used to assess mtDNA variation. Each enzyme results in a mtDNA fragment pattern, and the patterns for the two enzymes compose a haplotype for each bear. The haplotypes have a low level of DNA sequence divergence (0.003–0.006 substitutions/nucleotide). A test for variance in haplotype frequency among subpopulations was conducted using a molecular analysis of variance (AMOVA) to calculate ϕ_{ST} using program Arlequin version 2.0 (Schneider et al. 2000). We also compared the numbers of each haplotype in the Beaufort and Chukchi seas for males and females separately with χ^2 contingency tests.

Table 2. Mitochondrial DNA (mtDNA) haplotype frequencies and allelic richness (AR) of polar bears captured in the southern Beaufort Sea and Chukchi Sea of northern Alaska.

	Beaufort Sea (N = 51)	Chukchi Sea (N = 47)
mtDNA		
PB1	0.7647	0.7872
PB2	0.2157	0.1489
PB3	0.0196	0.0638
AR	3.0	3.0

Results

Genotypes were obtained at eight microsatellite DNA loci for 116 bears captured in the southern Beaufort Sea and 127 bears captured in the Cbukchi Sea (Table 1). We observed 4–9 alleles at the eight microsatellite loci, with an average of 6.9 alleles per locus in the southern Beaufort Sea and 7.0 alleles per locus in the Chukchi Sea. Allelic richness was 6.9 alleles per locus in both areas. Overall observed heterozygosity was 0.652 in the southern Beaufort samples and 0.639 in the Chukchi samples, and overall expected heterozygosity was 0.641 in the southern Beaufort samples and 0.637 in the Chukchi samples. Samples from both areas were in Hardy–Weinberg equilibrium at each locus ($P > 0.06$) and at all loci combined ($P > 0.3334$). Hardy–Weinberg equilibrium also was apparent at each locus ($P > 0.1193$) and at all loci combined ($P > 0.5115$) when all of the Chukchi and Beaufort sea samples were pooled into one group. We found no significant associations of loci ($P > 0.0646$), suggesting that the microsatellite loci are not linked (Paetkau et al. 1999).

Microsatellite allele frequencies in the Cbukchi and southern Beaufort sea samples were not significantly different. The eight-locus F_{ST} value was not significantly different from zero ($F_{ST} = -0.0002$) and the tests of heterogeneity showed that the allele frequencies did not differ significantly ($P = 0.0827$) between the southern Beaufort and Chukchi samples over the eight loci combined (Table 1). Results of the Bayesian analysis without a priori assignment of individuals to populations indicated that the number of genetic populations most consistent with the data was $K = 1$.

We obtained mtDNA restriction fragment patterns for the *Hin*dIII and *Cla*I restriction enzymes for 51 bears from the southern Beaufort Sea and 47 bears from the Chukchi Sea. Three mtDNA haplotypes were identified in polar bears from the Beaufort and Chukchi seas (Table 2), as in previous analyses (Cronin et al. 1991). Haplotype PB1 predominated in both areas (76%–79%), haplotype PB2 was the second most abundant in both areas (15%–22%), and haplotype PB3 was the least common in both areas (2%–6%). mtDNA haplotype frequencies did not differ significantly between the southern Beaufort and Chukchi seas ($\phi_{st} = -0.006$). Of the 51 bears from the southern Beaufort Sea for which mtDNA haplotypes were determined and the sex was known, 12 were males and 30 were females. The sex was not known for nine of the southern Beaufort Sea bears. Of the 47 bears from the Chukchi sea for which mtDNA haplotypes were determined, 6 were males and 41 were females. mtDNA haplotype frequencies did not differ significantly between the Beaufort and Chukchi seas for males ($P = 0.6775$) or females ($P = 0.2294$).

Discussion

The frequencies of microsatellite alleles and mtDNA haplotypes of polar bears captured in the Chukchi Sea and southern Beaufort Sea were not significantly different, and the microsatellite genotypes of the combined samples from the two areas were consistent with expected Hardy–Weinberg proportions (i.e., no Wahlund effect). This suggests that there is no genetic subdivision, and bears from the Chukchi Sea and southern Beaufort Sea can be considered to be one interbreeding population. This result corroborates previous studies, based upon smaller sample sizes, that suggested little genetic differentiation between bears from the southern Beaufort and Chukchi seas (Cronin et al. 1991; Scribner et al. 1997; Paetkau et al. 1999).

There are three geographic scales of interest regarding the population genetic structure of polar bears: adjacent subpopulations, subpopulations across the north polar basin, and subpopulations across the worldwide distribution of polar bears. At the scale of geographically adjacent subpopulations, our data indicate no genetic differentiation between bears from the southern Beaufort and Chukchi seas. There is more differentiation of microsatellite allele frequencies across the larger geographic scale of the north polar basin. The average pairwise F_{ST} (0.013) for 16 microsatellite loci among polar bears from six Arctic locations across the north polar basin (including the northern and southern Beaufort seas, the Chukchi Sea, the Siberian Arctic, Svalbard archipelago, and eastern Greenland; Paetkau et al. 1999) was higher than our F_{ST} (–0.0002) between the adjacent Beaufort and Chukchi sea subpopulations. On the worldwide geographic scale, there is considerable genetic differentiation among polar bears in four major geographic regions: the north polar basin; the Norwegian Bay area of northern Canada; the Canadian Arctic archipelago; and areas in Canada and Greenland south of the Canadian Arctic archipelago, including Hudson Bay, Davis Strait, and the Foxe Basin (Paetkau et al. 1999). Average pairwise F_{ST} between these regions was higher (0.050) than the average pairwise F_{ST} within these regions (0.013). These patterns of genetic differentiation are thought to be due primarily to differences in the seasonal distribution of sea-ice habitat between the high Arctic land masses (Paetkau et al. 1999). Across the north polar basin, including the Chukchi and Beaufort seas, sea ice is continuous and there are no barriers to movement of polar bears. In contrast, differing patterns of distribution of ice and land masses may constitute barriers to gene flow among the four regions that show a higher degree of genetic differentiation.

Our data show that polar bears are not genetically differentiated between the Chukchi and Beaufort seas, despite movement data showing high range fidelity. The combined genetic and field data indicate the potential for discordance between direct (animal movements) and indirect (molecular genetic) measures of gene flow (Slatkin 1987). Genetic homogeneity may result from relatively low level of continuous gene flow, episodic gene flow, or recent common ancestry of currently segregated subpopulations. The range overlap and movements of polar bears between the Beaufort and Chukchi seas suggests that there is probably enough continuous gene flow to maintain genetic homogeneity over these areas. Lack of genetic differentiation as revealed by both maternally inherited mtDNA and bi-parentally inherited microsatellite DNA suggests that gene flow between the Chukchi and southern Beaufort seas is mediated by both sexes. This is consistent with radiotelemetry and tag-recovery data showing that male and female polar bears have similar range sizes and movement patterns in these areas (Amstrup et al. 2000, 2001).

The discrepancy between genetic and movement data may also be due to collection of movement data primarily from adult female bears, which exhibit high fidelity to ranges. Therefore, the radiotelemetry data would not record dispersal and gene flow between subpopulations. However, some of the adults sampled for genetic analysis may have immigrated as subadults prior to being captured and radio-collared. The genetic analysis would thus include adults born in the subpopulation and adults that immigrated into the subpopulation as subadults, and thus reflect gene flow over time. Subadult bears might disperse more than adult females, as Taylor et al. (2001) found that subadult polar bears of both sexes travel more widely than adults, although they usually return to near their natal area by the time they reach sexual maturity. Additional research is needed to understand the movements of adult and subadult polar bears and the resulting gene flow in the Beaufort and Chukchi seas.

In the context of management and conservation, our results suggest that problems associated with small, isolated subpopulations are not manifested in polar bears in the southern Beaufort Sea and Chukchi Sea. It appears that immigration and emigration between the southern Beaufort and Chukchi seas facilitate gene flow and maintain genetic diversity. These data also suggest that reductions in numbers of bears in one area could be compensated by immigration from the adjacent area, and the bears in our study areas could be considered to be one population. However, factors other than genetics need to be considered in identifying units for management (Cronin 1993, 2006). For example adult females have high fidelity to ranges, and are critical from a management standpoint because of the importance of production and recruitment of new bears (Taylor et al. 1987). Therefore, it is appropriate to manage polar bears in the Beaufort and Chukchi seas as separate subpopulations despite the genetic homogeneity. Other factors that differ between the bear ranges in the southern Beaufort Sea and Chukchi Sea, such as seasonal movements of sea ice, also suggest that they should be treated as separate management units (Amstrup et al. 2000). Considering the combined genetic and movement data, it is appropriate to consider the polar bears from the southern Beaufort Sea and Chukchi Sea as subpopulations of a combined southern Beaufort and Chukchi population.

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CRS Report for Congress

Polar Bears: Proposed Listing Under the Endangered Species Act

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Polar Bears: Proposed Listing Under the Endangered Species Act

Summary

The proposed listing of polar bears as threatened under the Endangered Species Act (ESA; 16 U.S.C. §§1531 et seq.) highlights the intersection of two significant issues currently before Congress — climate change and species protection. According to the ESA, this listing decision rests solely on an interpretation of the best available scientific understanding of the species and how it may be affected by changes in its habitat.

Polar bears depend on Arctic sea ice, which most scientists acknowledge will be affected by climate warming causing, at minimum, an earlier annual or seasonal thaw and a later freeze of coastal sea ice. Globally, less than one-third of the 19 known or recognized polar bear populations are declining, more than one-third are increasing or stable, while the remaining third have insufficient data available to estimate population trends and their status has not been assessed. Two of these polar bear populations occur within U.S. jurisdiction.

Polar bears are affected by climate change, contaminants, and subsistence and sport hunting. Environmental organizations have voiced public concern that polar bears were threatened by climate change. Scientists have confirmed that, in recent decades, the extent of Arctic sea ice has declined significantly as the result of climate warming: annual ice break-up in many areas is occurring earlier and freeze-up later, Arctic sea ice is experiencing a continuing decline that cannot easily be reversed, and some models project that Arctic sea ice will disappear completely by the second half of this century. Three main groups of contaminants are implicated as potentially threatening polar bears — petroleum hydrocarbons, persistent organic pollutants, and heavy metals. The United States allows limited subsistence harvest of polar bears by Alaska Natives. In Canada, Native hunters are permitted to allocate a limited portion of the subsistence harvest to sport hunters. Under 1994 amendments to the MMPA, U.S. citizens may obtain permits to import sport-harvested polar bear trophies from Canada.

The Fish and Wildlife Service (FWS) has proposed listing polar bears as a threatened species under ESA, acknowledging the increasing threats to their existence. The FWS listing decision must be based solely on the best available scientific and commercial information regarding five factors: habitat destruction, overutilization, disease or predation, inadequacy of other regulatory mechanisms, and other natural or manmade factors.

Controversy exists over how great a threat the changing climate might be to polar bears and whether they might be able to adapt to these changing conditions. Some point out that polar bears today are not coping with changing climate alone, but also face a host of other human-induced factors — including shipping, oil and gas exploration, contaminants, and reduced prey populations — that compound the threat to their continued existence. There is also considerable uncertainty in estimates of polar bear population numbers and trends as well as in our understanding of polar bear habitat.

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Background

The polar bear, *Ursus maritimus*, is the largest terrestrial carnivore and a top predator, inhabiting circumpolar Arctic regions wherever sea ice is present for a substantial part of the year. Nineteen known or identified populations of polar bears have an estimated total abundance of 20,000 to 25,000 animals (**Figure 1**). Two of these populations occur within U.S. jurisdiction — the Southern Beaufort Sea population (shared about equally with Canada) is estimated at 1,526 animals,[1] while the Chukchi/Bering Seas population (shared with Russia) is estimated at about 2,000 animals.[2] Polar bear populations are in decline in Western Hudson Bay and may be starting to decline in the Southern Beaufort Sea. Simulations suggest that polar bear populations are also declining in Baffin Bay, Kane Basin, and Norwegian Bay. Globally, less than one-third of the 19 populations are declining, and more than one-third are increasing or stable, while the remaining third have insufficient data available to estimate population trends and their status has not been assessed.[3] The status of the polar bear in the Central Arctic Basin, the largest population, is unknown. Large carnivorous mammals are generally considered to be most at risk of population declines and extinctions,[4] and the minimum viable total population of polar bears has been estimated at 4,961 individuals.[5]

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[1] E. V. Regehr, S. C. Amstrup, and I. Stirling, *Polar Bear Population Status in the Southern Beaufort Sea*, U.S. Geological Survey, Open File Report 1337 (2006).

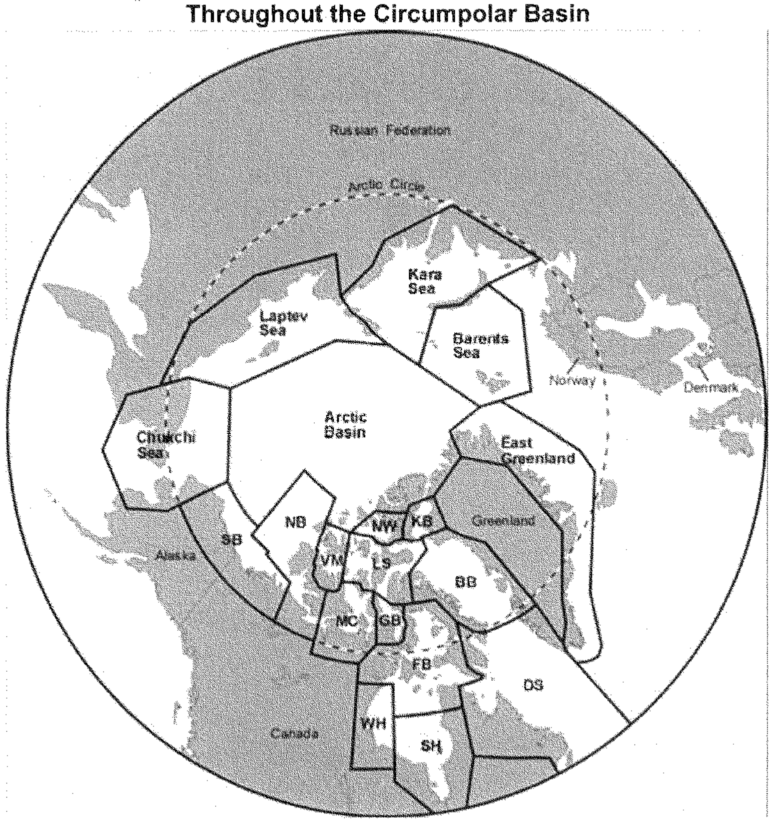
[2] This abundance estimate, by the Polar Bear Specialist Group (see footnote 3), has low confidence, with no estimate of precision or bias.

[3] Polar Bear Specialist Group, *Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group*, Occasional Paper of the IUCN Species Survival Commission No. 32 (2006), p. 34-35, available at [http://pbsg.npolar.no/docs/PBSG14proc.pdf].

[4] M. Cardillo et al., "Multiple Causes of High Extinction Risk in Large Mammal Species," *Science*, v. 309, no. 5738 (Aug. 19, 2005): 1239-1241.

[5] D. H. Reed et al., "Estimates of Minimum Viable Population Sizes for Vertebrates and Factors Influencing Those Estimates," *Biological Conservation*, v. 113, no. 1 (September 2003): 23-34.

Figure 1. Distribution of Polar Bear Populations Throughout the Circumpolar Basin



Source: Polar Bear Specialist Group, *Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group*, p. 33. SB = Southern Beaufort Sea, NB = Northern Beaufort Sea, VM = Viscount Melville, NW = Norwegian Bay, LS = Lancaster Sound, MC = McClintock Channel, GB = Gulf of Boothia, FB = Foxe Basin, WH = Western Hudson Bay, SH = Southern Hudson Bay, KB = Kane Basin, BB = Baffin Bay, DS = Davis Strait.

The primary prey of polar bears is the ringed seal — a polar bear may stalk a seal by waiting quietly for it to emerge from an opening in the ice that seals make to breathe or climb out of the water to rest. Ringed seals have a circumpolar distribution and are associated with ice year-round. Much of ringed seal habitat (especially in offshore drifting sea ice) has not been surveyed, leading to much uncertainty regarding population size and status. Current estimates of the global population numbers for ringed seal range from more than 2 million to as many as 7 million animals. Other prey include bearded and harp seals, juvenile walrus, beluga whales, narwhal, fish, and seabirds and their eggs. Over most of their range, polar bears remain on the sea ice year-round or spend at most only short periods on land. In October and November, male polar bears head out onto sea ice where they spend the winter.

Polar bears have one of the lowest reproductive rates of any mammal, with mature females reproducing once every three years. Pregnant females either seek sites on the sea ice ("pelagic bears") or on mainland areas ("nearshore bears") to dig large dens in snow where they give birth and spend the winter.[6] Females do not require mainland sites for denning, but some individuals seem to prefer them. Both pelagic and nearshore individuals are known in all subpopulations studied.[7]

Currently, polar bears are protected and managed under domestic law and several international agreements. Because the primary habitat of the polar bear is sea ice and this species is evolutionarily adapted to life at sea, it is managed as a marine mammal. In the United States, polar bears are protected under the Marine Mammal Protection Act (MMPA; 16 U.S.C. §§1361 et seq.), with the Fish and Wildlife Service (FWS) in the Department of the Interior as the federal management agency. The Alaska Nanuuq Commission, a Native organization representing villages in northern and northwestern Alaska, has a co-management agreement with the FWS to provide input on matters related to the conservation and sustainable use of polar bears.[8]

Internationally, the multilateral 1973 Agreement on the Conservation of Polar Bears[9] and the 2000 bilateral Agreement Between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population[10] provide a basis for cooperation on polar bear management. In addition, Alaska and Canada exercise joint cross-border management through the Inuvialuit-Inupiat Polar Bear Management Agreement for the Southern Beaufort Sea.[11] The International Union for the Conservation of Nature (IUCN) classifies the polar bear as *vulnerable* on the IUCN Red List of Threatened Species. The IUCN classification of *vulnerable* represents a judgment that the species is facing a high risk of extinction in the wild.[12]

In addition, polar bears are listed on Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES). Appendix II contains species not necessarily threatened with extinction but requiring controlled

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[6] U.S. Dept. of the Interior, Fish and Wildlife Service, "Polar Bear Fact Sheet," available at [http://www.fws.gov/home/feature/2006/polarbear.pdf], and "Polar Bear Questions and Answers," available at [http://www.fws.gov/home/feature/2006/PolarbearFAQ.pdf].

[7] Mette Mauritzen, Andrew E. Derocher, and Oystein Wiig, "Space-Use Strategies of Female Polar Bears in a Dynamic Sea Ice Habitat," *Canadian Journal of Zoology*, v. 79 (Sept. 2001): 1704-1713.

[8] See [http://www.nanuuq.info/index.html].

[9] Parties to this agreement are Canada, Denmark, Norway, the Russian Federation, and the United States. See [http://sedac.ciesin.org/entri/texts/polar.bears.1973.html].

[10] See [http://alaska.fws.gov/media/pbsigning/agreement.html].

[11] See [http://pubs.aina.ucalgary.ca/arctic/Arctic55-4-362.pdf].

[12] This assessment is based on a suspected population decline of more than 30% within three generations (45 years) due to decline in area of occupancy, extent of occurrence, and habitat quality.

trade to prevent population declines, as well as other species whose body parts are difficult to distinguish by visual inspection (the so-called "look-alike" problem, in this case in controlling trade in bear gall bladders).[13] ESA implements CITES provisions domestically. As such, ESA affords protection to endangered species and wildlife of global concern. To complement CITES, ESA specifically prohibits interstate and foreign commerce in ESA-listed species. FWS agents and inspectors work to control any illegal trade and international movement of CITES- and ESA-listed species, since some species found in other countries may be brought into the United States by activities that could threaten their long-term survival. ESA is applicable to activities within U.S. jurisdiction, as well as activities by U.S. citizens anywhere, including the high seas.

Circumstances Affecting Polar Bears

Climate Change[14]

Climate change is widely believed to be one of the most significant contemporary threats to biodiversity worldwide.[15] A May 2002 report by the World Wildlife Fund raised public concern that polar bears were threatened by climate change.[16] Scientists have confirmed that, in recent decades, the extent of Arctic sea ice has declined significantly as the result of climate warming: annual ice break-up in many areas is occurring earlier and freeze-up later, Arctic sea ice is experiencing a continuing decline that it is thought may not easily be reversed,[17] and some models project that Arctic sea ice could disappear completely by the second half of this century.[18]

Distribution patterns of some polar bear populations have changed in recent years. Greater numbers of bears are being found onshore near the Bering Sea,[19] and

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[13] For additional background on CITES, see CRS Report RL32751, *The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES): Background and Issues*, by Pervaze A. Sheikh and M. Lynne Corn.

[14] For background on climate change, see CRS Report RL33849, *Climate Change: Science and Policy Implications*, by Jane Leggett.

[15] C. D. Thomas et al., "Extinction Risk from Climate Change," *Nature*, v. 427, no. 6970 (Jan. 8, 2004): 145-148; Arctic Climate Impact Assessment, *Impacts of a Warming Arctic: Arctic Climate Impact Assessment* (Cambridge University Press, 2005), 144 p.

[16] Stefan Norris, Lynn Rosentrater, and Pal Martin Eid, *Polar Bears at Risk* (World Wildlife Fund, May 2002), available at [http://www.ngo.grida.no/wwfap/polarbears/risk/PolarBearsAtRisk.pdf].

[17] R. W. Lindsay and J. Zhang, "The Thinning of the Arctic Sea Ice, 1988-2003: Have We Passed a Tipping Point?" *Journal of Climate*, v. 18, no. 22 (2005), pp. 4879-4894.

[18] Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis*, Summary for Policymakers (Geneva, Switzerland: February 2007), 21 pp.

[19] S. L. Schliebe, T. Evans, S. Miller, and J. Wilder, "Fall Distribution of Polar Bears along

(continued...)

in some parts of Canada,[20] with Inuit hunters reporting more bears present on land during summer and fall.[21] There may be several reasons for the observed changes, including changes in sea ice; those who conduct population censuses of polar bears will need to be cautious in interpreting whether apparent population variations are indicative of different habitat use (e.g., greater numbers of bears onshore) or actual changes in population abundance.

The projected loss of sea ice could affect survival and reproduction of polar bears by:

- shortening the season during which ice is available to serve as a platform for hunting seals;[22]
- increasing the distance between the ice edge and land, thereby making it more difficult for nearshore female bears that prefer to den on land to reach preferred denning areas;
- reducing the availability of sea ice dens for gestating pelagic female bears;
- requiring nearshore bears to travel through fragmented sea ice and open water, which uses more energy than walking across stable ice formations;[23]
- reducing the availability and accessibility of ice-dependent prey, such as ringed seals, to nearshore populations;[24] and

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[19] (...continued)
Northern Alaska Coastal Areas and Relationship to Pack Ice Position," in *Collection of Scientific Papers from the 4th International Conference of Marine Mammals of the Holarctic*, V. M. Belkovich, ed. (St. Petersburg, Russia: 2006), p. 559.

[20] E. K. Parks, et al., "Seasonal and Annual Movement Patterns of Polar Bears on the Sea Ice of Hudson Bay," *Canadian Journal of Zoology*, v. 84, no. 9 (September 2006): 1281-1294.

[21] Unpublished reports in 2005 by M. Dowsley and M. Taylor, as cited in the FWS polar bear status assessment report (see footnote 41).

[22] For every week earlier the sea ice breaks up, bears come ashore 10 kilograms lighter in weight, on average. See Ian Stirling and A.E. Derocher, "Possible Impacts of Climatic Warming on Polar Bears," *Arctic*, v. 46 (1993): 240-245.

[23] Loss of sea ice forces polar bears to cross large expanses of water and increases risk of drowning. In 2004, scientists documented polar bears swimming as far as 60 miles offshore and observed 4 drowned bears. See C. Monnett and J.S. Gleason, "Observation of Mortality Associated with Extended Open-Water Swimming by Polar Bears in the Alaskan Beaufort Sea," *Polar Biology*, v. 29, no. 8 (July 2006): 681-687.

[24] I. Stirling and C. L. Parkinson, "Possible Effects of Climate Warming on Selected Populations of Polar Bears (*Ursus maritimus*) in the Canadian Arctic," *Arctic*, v. 59, no. 3 (September 2006): 261-275; S. H. Ferguson, I. Stirling, and P. McLoughlin, "Climate Change and Ringed Seal (*Phoca hispida*) Recruitment in Western Hudson Bay," *Marine Mammal Science*, v. 21, no. 1 (Janaury 2005): 121-135.

- requiring nearshore bears to spend more time on land, thereby increasing the potential for adverse human-polar bear interactions.[25]

In addition to changing sea ice conditions, climate change might affect the integrity of polar bear den sites, as rain can destroy ice dens, exposing young polar bears to the elements prematurely.[26]

Although some scientists predict the extinction of polar bears under potential climate change scenarios, not all sea-ice changes would harm polar bears. For example, reduced sea ice thickness and coverage in far northern regions is likely to improve polar bear habitat, by increasing the availability and accessibility of ice-dependent prey, such as ringed seals.[27] Others remind biologists that climate-related changes to a species' distribution does not necessarily result in changes in abundance.[28]

Contaminants

Three main groups of contaminants are implicated as potentially threatening polar bears — petroleum hydrocarbons, persistent organic pollutants, and heavy metals. Polar bears are particularly vulnerable to oil spills, because oil damages polar bear fur (decreasing the bears' ability to thermoregulate) and because of oil ingestion (poisoning) via grooming and/or eating contaminated prey.[29] Although elevated concentrations of some persistent organic pollutants have been discovered in polar bears, it has been difficult to determine what biological effects these chemicals might have on polar bears; weakened immune systems and reduced reproductive success are among the concerns.[30] Some persistent organic pollutants are endocrine disruptors and are thought to cause pseudo-hermaphrodism and aberrant genital morphology in polar bears.[31] Mercury is a particular concern because of its toxicity at low concentration, and its magnification and accumulation through the food web. However, polar bears appear able to demethylate (i.e., alter the chemical form and biological reactivity of) mercury and accumulate somewhat elevated levels of

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[25] Marine Mammal Commission. *Annual Report to Congress, 2005* (Bethesda, MD: July 15, 2006), p. 52.

[26] Stefan Norris, Lynn Rosentrater, and Pal Martin Eid, *Polar Bears at Risk* (World Wildlife Fund, May 2002).

[27] A. E. Derocher, N. J. Lunn, and I. Stirling, "Polar Bears in a Warming Climate," *Integrative and Comparative Biology*, v. 44, no. 2 (April 2004): 163-176.

[28] C. J. Krebs and D. Berteaux, "Problems and Pitfalls in Relating Climate Variability to Population Dynamics," *Climate Research*, v. 32 (2006): 143-149.

[29] D. J. St. Aubin, "Physiologic and Toxic Effects on Polar Bears," in *Sea Mammals and Oil: Confronting the Risks*, J. R. Geraci and D. J. St. Aubin, eds. (New York, NY: Academic Press, Inc., 1990), p. 235-239; N. A. Oritsland, et al., *Effect of Crude Oil on Polar Bears*, Environmental Studies No. 24, Northern Affairs Program, Northern Environmental Protection Branch, Indian and Northern Affairs, Canada (1981), 268 pp.

[30] J. U. Skarre et al., "Ecological Risk Assessment of Persistent Organic Pollutants in the Arctic," *Toxicology*, v. 181-182 (2002): 193-197.

[31] C. M. Fossi and L. Marsili, "Effects of Endocrine Disruptors in Aquatic Mammals," *Pure and Applied Chemistry*, v. 75, nos. 11-12 (Nov.-Dec. 2003): 2235-2247.

mercury without harm.[32] Climate change may alter contaminant pathways through increased precipitation, increasing the potential threat to polar bears.[33]

Subsistence and Sport Harvest

The United States allows limited subsistence harvest of polar bears by Alaska Natives. Subsistence harvest of depleted, threatened, and endangered marine mammals can be managed in different ways. Due to concerns for depleted beluga whales in Cook Inlet, AK, subsistence harvest by Alaska Natives has been severely restricted (0 to 2 animals annually) since 1999.[34] On the other hand, a substantial Alaska Native subsistence harvest of endangered bowhead whales continues, with 75 whales permitted to be struck in 2006.[35] In the year from July 1, 2004, through June 30, 2005, Alaska Natives harvested 27 polar bears from the Southern Beaufort Sea population and 33 polar bears from the Chukchi/Bering Seas population. In addition, there is particular concern for the Chukchi/Bering Seas population due to anecdotal evidence that unregulated harvest by Russian Natives on the Chukotka Peninsula may be reaching unsustainable levels.[36]

In Canada, Native hunters are permitted to allocate a limited portion of the subsistence harvest to sport hunters.[37] Under 1994 amendments to the MMPA, U.S. citizens may obtain permits to import sport-harvested polar bear trophies from Canada, taken under scientifically sound quotas ensuring the maintenance of the affected population at a sustainable level.[38] In 2006, FWS issued 72 permits for importing polar bear trophies from Canada, with more than half taken from the Lancaster Sound population.

Habitat damage from climate change may interact with subsistence and sport harvest to increase polar bear mortality. For example, large adult male bears, more likely to be targeted by hunters, may also be more at risk from the effect of climate change on prey availability since larger bears require greater amounts of food. In addition, male bears also disperse greater distances than females and thus could be more affected by the necessity to swim increasing distances.

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[32] Arctic Monitoring and Assessment Programme, *AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic* (Oslo, Norway: 2005), p. 123.

[33] R. W. Macdonald, T. Harner, and J. Fyfe, "Recent Climate Change in the Arctic and Its Impact on Contaminant Pathways and Interpretation of Temporal Trend Data: Review Article," *Science of The Total Environment*, v. 342, no. 1-3 (Apr. 1, 2005): 5-86.

[34] 71 *Fed. Reg.* 15697-15698 (Mar. 29, 2006).

[35] 71 *Fed. Reg.* 7539 (Feb. 13, 2006).

[36] Marine Mammal Commission. *Annual Report to Congress, 2005* (Bethesda, MD: July 15, 2006), p. 50-51.

[37] M. M. R. Freeman and G. W. Wenzel, "The Nature and Significance of Polar Bear Conservation Hunting in the Canadian Arctic," *Arctic*, v. 59, no. 1 (2006): 21-30.

[38] P.L. 103-238, §§4, 5; 16 U.S.C. §1371(a)(1); 16 U.S.C. §1374(c)(5).

Protection Efforts

On February 17, 2005, FWS received a petition from the Center for Biological Diversity requesting that FWS list the polar bear as threatened under ESA throughout its range and that it designate critical habitat for this species.[39] The Natural Resources Defense Council and Greenpeace, Inc., joined as petitioners on July 5, 2005. On December 15, 2005, the petitioners filed a complaint, challenging FWS's failure to issue a 90-day finding on the petition. On February 7, 2006, FWS announced a finding that the petition presented substantial scientific information indicating that listing the polar bear might be warranted, and subsequently announced the initiation of a formal status review.[40]

In a settlement agreement, approved on July 5, 2006, FWS agreed to submit a 12-month finding on the petition by December 27, 2006. On January 9, 2007, FWS announced its 12-month finding on the petition — concluding that, after a review of scientific and commercial information, listing the polar bear as a threatened species under ESA was warranted — and formally proposed such listing.[41] This proposed rule does not designate critical habitat for the polar bear. A 90-day period (through April 9, 2007) was announced to receive data and comments, with requests for a public hearing accepted for 45 days (through February 23, 2007). A decision on whether to list polar bears is due from FWS in January 2008.

The Secretary of the Interior must decide whether to list polar bears under ESA based only on the best available scientific and commercial (i.e., trade) information,[42] after an extensive series of procedural steps to ensure public participation and the collection of relevant information. The listing decision considers information relating to five factors: habitat destruction, overutilization, disease or predation, inadequacy of other regulatory mechanisms, and other natural or manmade factors.[43] At this point in the ESA process, the Secretary *may not* consider the economic effects that listing may have. The listing determination is the only place in ESA where

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[39] A species may be designated as either endangered or threatened, depending on the severity of its decline and threats to its continued survival. The prohibitions and penalties of ESA apply primarily to those species listed as endangered. Under § 4(d) of ESA, the Secretary may promulgate special regulations to address the plight of species listed as threatened. Protections and recovery measures for a particular threatened species can be tailored to particular situations. 50 C.F.R. §17.31 also affords threatened species for which a special rule has not been promulgated the same protections as endangered species. For additional background on ESA as well as regulatory procedures under this act, see CRS Report RL31654, *The Endangered Species Act: A Primer*, by M. Lynne Corn, Eugene H. Buck, and Pamela Baldwin.

[40] 71 *Fed. Reg.* 6745 (Feb. 9, 2006). Information on the status of the polar bear was solicited from the public in this notice and again in 71 *Fed. Reg.* 28653 (May 17, 2006).

[41] 72 *Fed. Reg.* 1064-1099 (Jan. 9, 2007). The polar bear status assessment document is available at [http://alaska.fws.gov/fisheries/mmm/polarbear/pdf/Polar_Bear_%20Status_Assessment.pdf].

[42] 16 U.S.C. §1533(b)(1)(A).

[43] 16 U.S.C. §1533(a)(1).

economic considerations are expressly forbidden; such considerations may enter in other stages, including critical habitat designation.

Economic factors cannot be taken into account at this stage because Congress directed that ESA listing be fundamentally a scientific question: is the continued existence of the species threatened or endangered? If polar bears were listed under ESA, federal agencies would be required to ensure that anything the federal government authorized, funded, or carried out that is likely to affect polar bears or their habitat would not jeopardize the survival of these bears or destroy or adversely modify their habitat.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is also reviewing the status of the polar bear in Canada. In addition, many would cite the multilateral 1973 Agreement on the Conservation of Polar Bears as a significant and substantive protection effort that provides international oversight of various national research and management programs.[44]

Controversy

Supporters of increased protection for polar bears argue that polar bears are the most iconic Arctic species, representing the Arctic as lions represent Africa. They further assert that it would be irresponsible to let the polar bear become extinct as a result of human action, and would be a terrible blow to the psyche of humankind. However, some critics suggest that the current proposal to list polar bears as threatened is premature, with this species being used as a "poster child" for the evils of climate change by the popular press in recognition of polar bears' charismatic appeal; some believe the less-glamorous walrus could be facing similar or greater immediate risk.

Some scientists also point out that, since polar bears have survived at least two major warming periods over the last 10,000 years, including the intense warming event that ended the Last Glacial Maximum about 8,000 to 9,000 years ago (when temperatures were believed to have been much warmer than now), polar bears and other Arctic mammals could be capable of adjusting, adapting, and coping with the current climatic change. At the end of the last Ice Age, the Northern Hemisphere entered an extended period of rapid warming, with temperatures in Arctic regions eventually reaching levels several degrees warmer than today. At that time, the sea ice above North America is known to have retreated substantially, allowing Arctic species such as bowhead whales and walrus to move northward into areas of the Canadian Arctic that they cannot reach today. The Mid-Holocene Warm Period peaked about 11,000-9,000 years ago near Alaska and about 8,000-5,000 years ago near Greenland and Northern Europe. In both areas, temperatures rose rapidly 10-15 degrees Centigrade to a point significantly warmer than present (about 2.5 degrees Centigrade warmer; but less than the temperatures projected by the

[44] P. Prestrud and I. Stirling, "The International Polar Bear Agreement and the Current Status of Polar Bear Conservation," *Aquatic Mammals*, v. 20, no. 3 (1994): 113-124.

Intergovernmental Panel on Climate Change for 2100), and about 5-10 degrees Centigrade of that warming took place within 30 years or less.[45]

Another significant but shorter warm period occurred about 1,000 years ago, when Arctic temperatures were slightly warmer than today. This warming also triggered sea ice reductions in Arctic regions and was accompanied by significant reductions in Greenland glaciers, creating so much arable land that Viking settlers established farms on the west coast of Greenland that were occupied for about 400 years.[46]

There is no evidence to suggest that ice in the Arctic Basin disappeared entirely during either of these warm periods or that any ice-dependent species became extinct. Polar bears and their primary prey existed before the last Ice Age and significant populations of them remain today. The tight association of polar bears and their prey species with moving sea ice gives them a flexibility that land-based carnivores do not have.

Others counter that polar bears today are not coping with changing climate alone, but also face a host of other human-induced factors — including shipping, oil and gas exploration, contaminants, and reduced prey populations — that compound the threat to their continued existence.[47] In addition, the opportunity for a catastrophic disease event is greater in populations subject to multiple stressors. Furthermore, they emphasize that current climate warming may be occurring at an accelerated rate, due to human influence, compared to past periods of climate warming, and species may be less capable of adapting to these more rapid changes.

Others suggest that there is considerable uncertainty in the estimates of polar bear population numbers and trends as well as in our understanding of polar bear habitat. Much of what we know about the polar bear habitat is confined to regions close to shore that have been studied during long summer days, with little known about what happens on drifting sea ice far from shore, especially in winter when there is little or no daylight. These critics also urge caution on interpreting studies of sea ice change that are based primarily on surveys of nearshore regions, rather than the drifting sea ice environment in the central Arctic Basin, where ice may be thickest. Recent studies conclude there is significantly more variability in ice thickness

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[45] D. S. Kaufman et al., "Holocene Thermal Maximum in the Western Arctic (0-180 Degrees W," *Quaternary Science Reviews*, v. 23, nos. 18-19 (October 2004): 2059-2060; Arthur S. Dyke, et al., "The Late Wisconsinan and Holocene Record of Walrus (*Odobenus rosmarus*) from North America: A Review with New Data from Arctic and Atlantic Canada," *Arctic*, v. 52, no. 2 (June 1999): 160-181; Arthur S. Dyke and James M. Savelle, "Holocene History of the Bering Sea Bowhead Whale (*Balaena mysticetus*) in its Beaufort Sea Summer Grounds off Southwestern Victoria Island, Western Canadian Arctic," *Quaternary Research*, v. 55 (2001): 371-379.

[46] Willie Soon and Sallie Baliunas, "Proxy Climatic and Environmental Changes of the Past 1000 Years," *Climate Research*, v. 23 (Jan. 31, 2003): 89-110.

[47] A. Shi, A. M. Bell, and J. L. Kerby, "Two Stressors are Far Deadlier Than One," *Trends in Ecology and Evolution*, v. 19 (2004): 274-276.

between years and regions than is predicted by climate models, which means that ice thickness can increase or decrease rapidly as well as differ among regions.[48]

Under ESA, the Secretary is required to take into account foreign polar bear conservation programs, including conservation hunting programs involving non-local (including U.S.) hunters. However, an ESA listing as "threatened" triggers an automatic listing as "depleted" under the MMPA, a listing that would prevent U.S. citizens from importing polar bear products into the United States. Such an import ban, effectively stopping U.S. participation in conservation hunting programs, is likely to seriously compromise successful Canadian community-based conservation programs.[49]

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[48] Seymour Laxon, Neil Peacock, and Doug Smith, "High Interannual Variability of Sea Ice Thickness in the Arctic Region," *Nature*, v. 425 (Oct. 30, 2003): 947-950.

[49] M. M. R. Freeman and G. W. Wenzel, "The Nature and Significance of Polar Bear Conservation Hunting in the Canadian Arctic," *Arctic*, v. 59, no. 1 (2006): 21-30.

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Viewpoint

Polar bears of western Hudson Bay and climate change: Are warming spring air temperatures the "ultimate" survival control factor?

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ABSTRACT

Long-term warming of late spring (April–June) air temperatures has been proposed by Stirling et al. [Stirling, I., Lunn, N.J., Iacozza, J., 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. Arctic 52, 294–306] as the "ultimate" factor causing earlier sea-ice break-up around western Hudson Bay (WH) that has, in turn, led to the poorer physical and reproductive characteristics of polar bears occupying this region. Derocher et al. [Derocher, A.E., Lunn, N.J., Stirling, I., 2004. Polar bears in a warming climate. Integr. Comp. Biol. 44, 163–176] expanded the discussion to the whole circumpolar Arctic and concluded that polar bears will unlikely survive as a species should the computer-predicted scenarios for total disappearance of sea-ice in the Arctic come true. We found that spring air temperatures around the Hudson Bay basin for the past 70 years (1932–2002) show no significant warming trend and are more likely identified with the large-amplitude, natural climatic variability that is characteristic of the Arctic. Any role of external forcing by anthropogenic greenhouse gases remains difficult to identify. We argue, therefore, that the extrapolation of polar bear disappearance is highly premature. Climate models are simply not skilful for the projection of regional sea-ice changes in Hudson Bay or the whole Arctic. Alternative factors, such as increased human–bear interaction, must be taken into account in a more realistic study and explanation of the population ecology of WH polar bears. Both scientific papers and public discussion that continue to fail to recognize the inherent complexity in the adaptive interaction of polar bears with both human and nature will not likely offer any useful, science-based, preservation and management strategies for the species.

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1. Introduction

Polar bears (*Ursus maritimus*) are charismatic megafauna that symbolize the Arctic. They play an important cultural, spiritual, mystical, and traditional role in the lives of Canadian Inuit through hunting and subsequent sharing of meat and fur. Additionally, Inuit-guided sport hunts provide important revenue for the economically challenged communities (Lee and Taylor, 1994). The latest research findings suggest, however, that this multi-purpose natural resource faces threats from climatic change and environmental stress (Stirling and Derocher, 1993; Stirling et al., 1999; World Wide Fund for Nature, 2002; Derocher et al., 2004) or from simply unsustainable harvests by human hunters (see recent discussion in Taylor et al., 2005).

Unfortunately, polar bears and their shrinking ice habitat are commonly used rhetoric to argue for the possible severity of climate change and global warming to the general public (cf., Washington Post, 2005). The polar bears that are most often cited are a specific population that inhabits the southwestern Hudson Bay coast—1 of 14 polar bear populations found in Canada (Derocher et al., 1998; Taylor et al., 2001). The area they occupy encompasses almost the southernmost extent of the species (only the southern Hudson Bay polar bear population reaches farther south; Derocher et al., 1998). Population stresses have been observed, which has led to the proposition that an earlier break-up of Hudson Bay ice (and an associated increase in spring air temperatures) is the cause of decreases in reproduction, subadult survival, and body mass of some of these bears (Stirling and Derocher, 1993; Stirling et al., 1999). A long-term warming trend of spring atmospheric temperatures was proposed, though not shown directly,[1] to be "the ultimate factor" (Stirling et al., 1999, p. 294). As a result, it is commonly believed that climatic changes (or "global warming") are the predominant factors leading to adverse conditions for the polar bear populations, although other factors have been acknowledged (e.g., density-dependent population responses; Derocher and Stirling, 1992).

We argue that there are several related stress factors that can explain the observed patterns in polar bear population ecology. Global warming may indeed have an effect on the polar bears of western Hudson Bay (WH) but it must be assessed in a more realistic framework that considers all the likely stress factors and their cumulative impacts. In such a context, it is difficult to isolate one factor of predominant severity and, consequently, it is simply not prudent to overstate the certainty of any single factor. As emphasized in Li (2004) and Loehle (2004), a full scientific understanding of an issue as complex as the population ecology of polar bears must necessarily requires the combined assessment of both the natural and social systems rooted in the problem rather than consideration of either component in isolation (i.e., warmer spring air temperatures and related sea-ice conditions in WH).

In the next two sections, we examine some of the potential nonclimatic causes of decreased reproduction, offspring survival, and body masses, including repeated bear–human interactions, food availability and competition. We then consider climatic factors by examining available surface air temperature records and ice dynamics in the Hudson Bay basin. Finally we synthesize these findings to critically evaluate the forecasts of polar bear extinction in relation to model projected scenarios of global warming by Derocher et al. (2004).

2. Human–polar bear interactions in western Hudson Bay

Western Hudson Bay polar bears have a long history of interactions and confrontations with humans. Stirling et al. (1977) discusses interactions between humans and WH polar bears from Churchill at dump sites, in town, and adjacent town areas. Over the years, the three main sources of bear–human interactions for the WH bears are activities related to (a) scientific research, (b) tourism, and (c) the Polar Bear Alert Program.

Research activities for the WH area began in 1966, and continue today as a long-term ecological monitoring project in which over 80% of the bear population is marked (Stirling et al., 1977; Lunn et al., 2002). The majority of this field work has been carried out by the Canadian Wildlife Service (CWS), although universities also conduct research on polar bears in the area. Many bears are captured, marked, and eventually recaptured, sometimes within the same year, over a number of years (e.g., Calvert et al., 1991a,b, 1995a,b, 1998). For example, from 1977 to 1995, an estimated total of 2772 bears were captured (Derocher and Stirling, 1995, their Tables 2 and 3; Lunn et al., 1997a, their Tables 2 and 3), with a minimum (i.e., since not all captures are clearly reported in publications and conflicting information exists) of about 1100 recaptures (recapture rates of between 52 and 90%; mean number of bears captured/year between 1977 and 1995 is about 145 bears; see summary total of columns 2 and 3 in Table 1). If one considers that the WH population estimate then was between 700 and 1200 bears (Amstrup and Wiig, 1991; Wiig et al., 1995), and about 15–30% of the population was captured and recaptured due to high fidelity to locations along the coast (Derocher and Stirling, 1990a,b), it is very likely that many bears were/are exposed to capture activities on a repeated basis.

An assumption most frequently made by researchers is that their work (i.e., capturing and handling wildlife repeatedly) has no significant effect on fitness, behaviour or survival of the wildlife species in question (Seber, 1973; Lehner, 1979). Long-term trends of handling polar bears were suggested by Ramsay and Stirling (1986) and included the possible effects on females with cubs. Although their study did not find any statistically significant results, the trends they presented indicated that females may suffer from handling by being displaced from feeding sites, possibly resulting in lowered body mass. Note that female polar bear body mass is positively related to cub survival (Derocher and Stirling, 1996, 1998a). If females lose body mass due to handling, cubs will be adversely affected in their survival rates. Also, most polar bear capture work occurs either on family groups in spring as they emerge from their dens, or during the ice-free period while bears are distributed along the southwestern shore of Hudson Bay—times when the bears are either stressed due to lactation (Arnould, 1990) or undergo a fasting period while living off their stored fat reserves (Watts

[1] Stirling et al. (1999) relied on the mean air temperature results of Skinner et al. (1998).

Table 1 – Captures of polar bears for research (males and females), for the Polar Bear Alert Program (PBAP), and total polar bear captures per year from 1977 to 1995

Year	Males[a]	Females[a]	PBAP[b]	Total captures/ year
1977	53	34	32	119
1978	29	26	16	71
1979	15	10	27	52
1980	20	29	18	67
1981	32	36	27	95
1982	68	42	32	142
1983	95	95	92	282
1984	96	63	18	177
1985	95	59	76	230
1986	84	53	26	163
1987	115	149	30	294
1988	140	152	35	327
1989	168	163	51	382
1990	107	92	64	263
1991	86	68	18	172
1992	57	74	54	185
1993	42	54	58	154
1994	63	64	79	206
1995	86	58	33	177
Total	1451	1321	786	3558
Mean	76	69	41	187

[a] Derocher and Stirling (1995); Tables 2 and 3, and Lunn et al. (1997a); Tables 2 and 3; whenever data were conflicting in their tables, we used the greater number for each gender/year.
[b] Kearney (1989), Calvert et al. (1991b, 1995b) and Lunn et al. (1998).

and Hansen, 1987). While the handling effect study of Ramsay and Stirling (1986) covered only 1967–1984, we suggest an additional analysis of capture–recapture data for handling effects that extends their time period to the present.

Almost concurrently with research activities at WH, some of the bears in the WH population are exposed to tourists and tourism activities during the fall. Since about 1980, polar bear viewing from large customized vehicles has been practiced near the town of Churchill. Polar bears leave the ice during June/July and slowly migrate north to the shores of Hudson Bay (approximately 35 km east of Churchill) where they congregate and wait the early freeze-up of the Bay, usually during November. Tour companies transport visitors into the congregation area (approximate coordinates are: 58°45′N to 58°48′N, and 93°38′W to 93°50′W) during October/November to view the bears (Dyck, 2001). Although the viewing period is short, usually between 1 October and 15 November, it is very intense, with about 6000 tourists and 15 large tundra vehicles per day in the area (Dyck and Baydack, 2006). Baiting, harassment and chasing of bears have been documented to occur (Watts and Ratson, 1989; Herrero and Herrero, 1997). The Polar Bear Technical Committee has expressed concern over these activities, suggesting that harassment of bears during this time of the year might be very stressful due to their fasting (Calvert et al., 1998). In the first baseline study conducted in the area to address tundra vehicle behaviour and vigilance (i.e., a motor act that corresponds to a head lift interrupting the ongoing activity) of resting polar bears, Dyck and Baydack (2004) found significant increases in vigilance behaviour of resting male polar bears in the presence of vehicles. The authors speculated that increased vigilance could lead to increased heart rates and metabolic activity, subsequently adding other factors that possibly contribute to the negative energy balance of bears while on land.

Another bear–human interaction occurs in the form of the Polar Bear Alert Program (PBAP) at Churchill. The Manitoba provincial management agency initiated the program in 1969 to protect local residents from bears, and vice versa (Kearney, 1989). The area around the town is patrolled, and bears that enter certain zones will either be deterred, captured, handled, or destroyed. From its inception up to 2000, an average of 48 bears per year (a total of 1547 bears) have been handled (Kearney, 1989; Calvert et al., 1991b, 1995b; Lunn et al., 1998; for a detailed PBAP description, see Kearney, 1989). Handling procedures are similar to those during research activities, and effects can be assumed to be similar.

Considering CWS-related research activities and the PBAP activities between 1977 and 1995, a total of 3558 bears (not including university-research handled bears) have been handled (last column in Table 1). This is about three times greater than the actual estimated WH population of 1100 (Derocher and Stirling, 1992), indicating that all bears are, on average, subject to repeated handling. Moreover, these activities occur when bears are either fasting or leaving their dens and are already energetically stressed. It is plausible that these repeated bear–human interactions have adversely stressed the bears over the past 30 years.

3. Food availability and competition

Between 1978 and 1990, the WH polar bear population was estimated to be around 1100 bears (Derocher and Stirling, 1992). Derocher and Stirling (1995) estimated the mean size of the population between 1978 and 1992 to be around 1000 bears. Up to 1997, the population did not change significantly, and was estimated to be around 1200 bears (Lunn et al., 1997a; Fig. 6 in Stirling et al., 1999). When published yearly population estimates from Derocher and Stirling (1995) and Lunn et al. (1997a) are examined, several tendencies are apparent. First, the Derocher and Stirling (1995) data for 1977–1992 show an increasing trend ($F = 4.16$, $p = 0.06$, $r^2 = 0.23$), although that trend is not statistically significant. Second, the Lunn et al. (1997a) data from 1984 to 1995 indicate a stable population ($F = 0.71$, $p = 0.42$, $r^2 = 0.07$). When both data sets are combined (i.e., the Derocher and Stirling (1995) data from 1977 to 1992 and the Lunn et al. (1997a) data for 1993–1995), a significant increase in the population size is implied ($F = 6.40$, $p = 0.02$, $r^2 = 0.27$). Most recently, however, it was noted that the population since 1995 has been declining to "less than 950 in 2004" (IUCN/Polar Bear Specialist Group, 2005). We clarify that the published estimate by Lunn et al. (1997a), combining Churchill and Cape Tatnam study area (both in WH) datasets, gives a 1995 WH polar bear population of 1233 with a 95% confidence interval that ranges from 823 to 1643 bears, so the actual confidence in the "decline" of the WH polar bear population in 2004, relative to the 1995 values, is difficult to confirm.

Given these long-term data on population estimates and responses, it is possible that density-dependent processes have been imprinted in the observed records of polar bears at WH. It is important, however, to recognize the great difficulties in demonstrating density dependence in population studies (e.g., Ray and Hastings, 1996; Mayor and Schaefer, 2005), among which is the sensitivity of the phenomenon on spatial scale covered by the population sampling techniques (e.g., Taylor et al., 2001). We concur with Derocher and Stirling (1995) and Stirling et al. (2004) that the WH population was at least stable during the 1984–1995 period (and likely up to 1997; see Stirling et al., 1999, their Fig. 6). Prior to that the WH population was hunted heavily, which led to hunting restrictions (Stirling et al., 1977; Derocher and Stirling, 1995). After the population recovered, and then increased, bear body mass, reproductive parameters, cub survival, and growth declined (Derocher and Stirling, 1992, 1998b). Derocher and Stirling (1992, 1995, 1998b) considered whether these responses reflect density-dependent population control mechanisms. They discarded them either because no accurate population estimates for WH existed, or no change in population size was detected. Typically, density-dependent responses, similar to those exhibited by WH polar bears, are detected in *increasing* populations (Eberhardt and Siniff, 1977; Fowler, 1990). By contrast, however, individuals of a population *near* carrying capacity (given that the WH population remained relatively stable for so long) can also exhibit traits that were observed for this polar bear population, namely poorer physical condition, lower survivorship, and lower rates of reproduction (Kie et al., 1980, 2003; Stewart et al., 2005). It is possible that the WH population has been stable for so long because carrying capacity has been reached, and intraspecific competition increased with increasing polar bear density, resulting in the documented responses.

It is important to note that the southern half of Hudson Bay is shared between polar bear populations of WH and southern Hudson Bay (SH) (Derocher et al., 1998). Polar bears of SH have exhibited better body condition as compared to their WH counterparts (Stirling et al., 1999, 2004) but prolonged ice conditions in that area seem not to be the explanation because

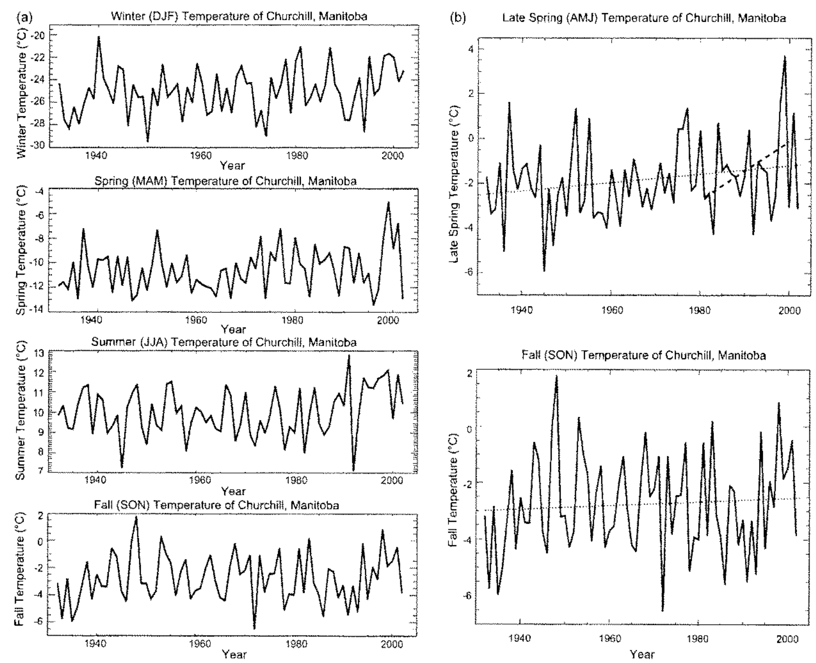

Fig. 1 – (a) Climatological winter (the average of December, January and February), spring (the average of March, April and May), summer (the average of June, July and August) and fall (the average of September, October and November) surface air temperatures of Churchill, Manitoba, which are assumed to be representative of temperatures around the western Hudson Bay from 1932 through 2002. (b) Late spring (defined as the average of April, May and June, following the discussion in Stirling et al., 1999; top panel) and fall (bottom panel) temperatures with statistically insignificant (i.e., with $p > 0.05$; again chosen in order to follow discussion in Stirling et al., 1999) trend lines (dotted) fitted through the 1932–2002 interval. The dashed trend line fitted through 1981–1999 verifies the late spring warming episode noted by Stirling et al. (1999) for that limited period.

recent updated analysis by Gagnon and Gough (2005a) suggested tendencies toward earlier ice break-up (hence shorter overall duration of sea-ice cover) in James Bay and along the southern shore of Hudson Bay. Population estimates, which have been conducted almost entirely via aerial surveys, indicate an increasing trend for this SH population from 1963 to 1996 (i.e., see Table 2 and Fig. 4c of Stirling et al., 2004). Although both populations are recognized as independent (e.g., Derocher and Stirling, 1990a,b; Kolenosky et al., 1992; Taylor et al., 2001), possible overlap can occur on the sea-ice. If population density for SH has been increasing, whereas food supply has been insufficient due to increased competition, then some SH bears may have expanded their hunting forays, leading to competition for food with WH bears. Yet there has not been a drastic decline in the WH population detected. One reason may be that the bears have learned to hunt seals during the ice-free period along the shores in tidal flats. This phenomenon has been observed for several years at Churchill in the polar bear viewing area (Dyck, personal observations).

Data on the bear food supply is needed to draw more clear conclusions about the interplay between population densities and worsening physical attributes of polar bears. The main prey of polar bears are ringed (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) (Stirling and Archibald, 1977; Smith, 1980), but seal population data are too limited at present to resolve this issue (Lunn et al., 1997b).

4. Air temperature and climate variability around Hudson Bay

Fig. 1a shows the surface air temperature records[2] of nearby Churchill, Manitoba (assumed here to be representative of WH) from 1932 to 2002 for the four climatological seasons. The large interannual variability of the seasonal temperatures suggests that establishing a meaningful long-term trend in any of these relatively short records would be difficult and that a trend determination, especially over short periods, will be highly sensitive to the time interval considered (e.g., Pielke et al., 2002; Cohen and Barlow, 2005). Fig. 1b attests that no statistically significant warming trend (dotted trend lines fitted over the full records in Fig. 1b) can be confirmed for either the late spring (defined here as the average of April, May and June, following discussion in Stirling et al., 1999) or fall seasons when the full record from 1932 through 2002 is considered. Thus, the hypothesis that a warming trend is the principal causative agent for the supposed earlier spring melt and later fall freeze of the sea-ice around WH cannot be confirmed. Further, that the temperature trend is not statistically different from zero indicates it is not obviously forced by anthropogenic greenhouse gases as commonly assumed and extrapolated to suggest implications for polar bear ecology in future scenarios of climate change. Such extrapolations remain premature at best.

An apparent tendency towards late spring warming can be derived by examining the period from 1981 to 1999, illustrated by the dashed trend curve in Fig. 1b. Clearly, the choice of end points is very influential on the results. The trend fails to persist when data through 2002 are included and we make no inferences about any concurrent ecological responses. Thus, although our independent results for temperature change and variability over the WH do not contradict Stirling et al. (1999) for the limited period from 1981 to 1999, the longer record reveals a fuller range of air temperature variability that argues against assuming a persistent warming trend.

Gough et al. (2004) recently identified snow depth as the primary governing parameter for the interannual variability of winter sea-ice thickness in Hudson Bay because of its direct insulating effect on ice surfaces. By contrast, the concurrent winter or previous summer air temperatures yield only weak statistical correlations with ice thickness. Detailed high-resolution modelling efforts by Saucier et al. (2004) that considers tides, river runoff and daily meteorological forcing, found tidal mixing to be critically important for ice-ocean circulation within, and hence the regional climate of, the Hudson Bay basin.

We further examined records of winter and spring air temperatures at Frobisher Bay (now called Iqaluit, Nunavut) by the Hudson Strait and the respective winter and spring Arctic Oscillation (AO) circulation indices[3] (Fig. 2) to better

[2] Our data source is the quality-controlled version of records from the NASA Goddard Institute for Space Studies web site: http://www.giss.nasa.gov/data/update/gistemp/station_data/. Churchill and Frobisher Bay data shown here are from the 7-station- and 5-station-merged records, respectively. Missing Churchill temperatures from NASA GISS database for 1993–1996 were replaced by data points from Churchill Airport given by CLIMVIS Global Summary of the day available from the U.S. National Climatic Data Center.

[3] Arctic Oscillation (AO) is a natural, planetary-scale pattern or mode of atmospheric circulation variability that is characterized by a seasaw of the air mass anomaly between the Arctic basin and the midlatitude zonal ring centered at about 45°N. A high (positive) AO value is defined as lower-than-normal atmospheric pressure over the Arctic and colder stratosphere, which are associated with strong subpolar westerlies. A low (negative) AO value represents higher-than-normal Arctic atmospheric pressure, less cold polar stratosphere and weak subpolar westerlies. The AO index is available from http://horizon.atmos.colostate.edu/ao/Data/index.html. Because of the relatively larger variability and stronger coupling of stratospheric and tropospheric air circulation during the cold season, AO is mainly a winter phenomenon However, AO has been demonstrated to be relevant to temperature and precipitation fields in other seasons as well (Gong and Ho, 2003; Kryjov, 2002; Overland et al., 2002). Please see Wallace (2000), Baldwin (2001) and Thompson and Wallace (2001) for complete tutorials. Although there have been several suggestions that the post-1969 or post-1989 AO index remained in an 'unusual', highly positive phase as a result of forcing by anthropogenic carbon dioxide, the current generation of climate models and modelling efforts are not sufficiently mature to confirm or refute such a proposal (Soon et al., 2001; Soon and Baliunas, 2003). Furthermore, it has been pointed out that AO index has been mostly neutral or negative in the most recent 9 years (1996–2004) despite the notable high-positive AO phase during the 1989–1995 interval earlier (e.g., Cohen and Barlow, 2005; Soon, 2005). Cohen and Barlow (2005) argued that even though the AO may contribute to regional warming in the Arctic and even the Northern Hemisphere for a particular period, but the pattern and magnitude of temperature signal induced by AO are physically quite different from the large-scale features produced by global warming trend in the last 30 years, thus disallowing any direct attribution of AO to radiative forcing by anthropogenic greenhouse gases.

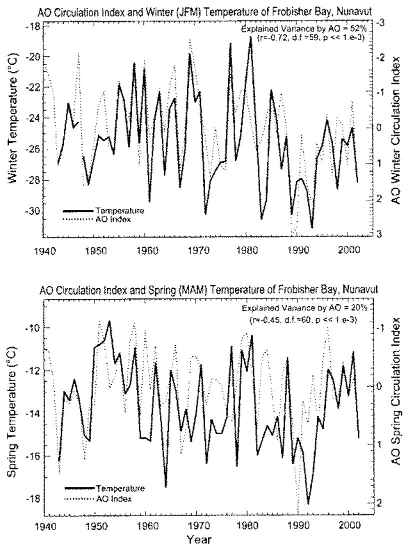

Fig. 2 – Statistically significant (i.e., $p \ll 0.001$) correlation between temperature (solid) at Frobisher Bay (now as Iqaluit), Nunavut and the Arctic Oscillation (AO) index (dotted) for winter (as averages of January, February and March; top panel) and spring (as averages of March, April and May; bottom panel). The axis for AO indices has a reversed scale such that high positive AO values mean colder temperatures at Frobisher Bay. 52% and 20% of the variance of the winter and spring temperatures for the 1943–2002 interval are explained by the respective AO indices. Both the standard Pearson's r and non-parametric Kendall's τ were computed, and statistical significance of the results are established based on both statistical measures.

characterize the regional pattern of air temperature variability. Fig. 2 shows two important points. First, note the rather strong cooling trend (at a rate of about 0.4 °C per decade since the 1950s) for the winter and spring temperatures of Frobisher Bay. Regional differences in the pattern of the temperature variability, especially on the multidecadal timescale, are large. This pattern of large temperature gradients between the southwestern and northeastern corners of the Hudson Bay oceanic basin has been well noted by Ball (1995), Catchpole (1995) and Skinner et al. (1998)—these authors also provided a comprehensive discussion on climate regimes around WH, including a broad, historical perspective on the range of natural variabilities. Among other things this indicates that a hypothesis of late spring warming negatively affecting the WH polar bear population ecology cannot be universally extended to other locations.

The second point of Fig. 2 is that the air temperature and climatic conditions around the Hudson Strait and Hudson Bay areas have a close association with the AO circulation index. The correlations shown in Fig. 2 are statistically significant, with AO variability explaining up to 20–50% of the interannual temperature variances at Frobisher Bay.

To examine the link between the AO index and Frobisher Bay air temperatures, both series were regressed on a matrix of monthly dummy variables to remove fixed seasonal effects. The residuals of these regressions (denoted AO_r and FR_r) were then tested in a vector autoregression to determine leading patterns of Granger causality (see Hamilton, 1994, Chapter 11). While AO_r shows a significant Granger-causal pattern on FR_r no such pattern exists in the other direction. This means the current value of the AO index significantly improves forecasts of monthly Frobisher Bay air temperatures, but the current air temperature does not improve forecasts of the AO. Finally, FR_r was regressed on its first two lags, AO_r and the first three lags of AO_r to remove serial correlation in the mean. After a trend term that was insignificant was removed, the r^2 from this regression was 0.39 (with an adj-r^2 of 0.38). A Wald test of the joint AO_r terms yielded a chi-square (d.f. = 4) statistic of 235.6. A p-value on the hypothesis of no influence of the current and lagged AO anomalies on the current monthly temperature anomaly is less than 0.00001.

The AO circulation index appears to be physically relevant for two reasons. First, from an examination of the statistics of sea level pressure and sea-ice motion from the 1979 to 1998 data collected by the International Arctic Buoy Programme, Rigor et al. (2002) confirmed that the AO circulation pattern can explain at least part of the thinning sea-ice trend observed over the Arctic Ocean. Polyakov and Johnson (2000) and Polyakov et al. (2003a) further emphasized the importance of the relative phasing of the decadal and multidecadal (i.e., 50–80 years) oscillatory modes of Arctic atmospheric circulation variability in explaining the recent Arctic sea-ice areal extent and thickness trends. Rigor et al. (2002) clarified that instead of assuming that the warming trend in surface air temperature caused the sea-ice to thin, it is the AO-induced circulation pattern that produces the tendencies for sea-ice to thin and sea-ice area to retreat (see further discussion on regional sea-ice trends and mechanisms in Zhang et al., 2000; Kimura and Wakatsuchi, 2001; Polyakov et al., 2003b; Söderkvist and Björk, 2004). In turn, it was the changes in sea-ice that caused the air temperature to warm because of an increasing heat flux from the interface with the ice-free ocean. Beyond atmospheric AO, Shimada et al. (2006) recently documented and highlighted the key role played by the inflows of warm Pacific summer water through the Bering Straits in causing the large sea-ice areal reduction in the Arctic that began in the late 1990s. Thus, such a complex physical picture connecting oceanic and atmospheric processes with sea-ice variability is dramatically different from Stirling et al. (1999)'s suggestion in which warm spring air temperature is considered to be the ultimate cause for the earlier spring sea-ice break-up[4] and poorer conditions of polar bears.

The second reason to discuss the AO index is related to a recent finding that climatic change effects associated with the AO index are propagated through two trophic levels within a high-arctic ecosystem (Aanes et al., 2002). From the statistical analyses of the 1987–1998 growth series of *Cassiope tetragona* (Lapland Cassiope) and the 1978–1998 abundance series of an introduced Svalbard reindeer (*Rangifer tarandus platyrhynchus*) population near Broggerhalvoya, on the NW coast of Svalbard, Aanes et al. (2002) found that high positive values of the AO index are associated with decreased plant growth and reindeer population growth rate. Thus, the reindeer population at Svalbard, through the mediation of the climate modulated effects on plant growth, is plausibly connected to climate through a bottom-up sequence. But Aanes et al. (2002) noted that the bottom-up scenario may be density-dependent in that at higher reindeer densities, a reverse top-down sequence of trophic interaction is becoming more important in which grazing has a dominating influence on the forage species and plant communities. The AO index is thus promising as a useful climatic variable for further examination of the dynamic of trophic interactions under various settings of the arctic ecosystem.

It must also be asked whether natural climate oscillations as those described above – reducing sea-ice cover and changing the freeze-and-thaw cycles that affect the food sources of polar bears at higher latitudes – are really as detrimental to biodiversity as suggested. These changes may create more polynyas, which are productive oases in the ice (Stirling, 1997), or increase marine productivity overall (Fortier et al., 1996; Rysgaard et al., 1999; Hansen et al., 2003) primarily because of the modulation of the food web of the lower trophic levels by freshwater-limiting and light-limiting processes. Bears do not feed year-round, but do feed during late spring when seal pups are abundant. More fat deposits may be accumulated during this time, and a "true hibernation state" like black (*U. americanus*) and brown bears (*U. arctos*) could become an evolutionary strategy for the remainder of the year for polar bears. This scenario could be very likely because polar bears evolved from brown bears (Kurtén, 1964). Alternatively, a supplementary feeding strategy could evolve where berries and vegetation are consumed in higher frequencies during the ice-free period, as has been observed for bears of Hudson Bay (Russell, 1975; Derocher et al., 1993).

5. Extrapolating polar bear populations

In light of these considerations we do not consider it a sound methodology to assume that local air temperature trends adequately explain WH population conditions and that extrapolating WH results generates predictions for polar bears and their habitat over the circumpolar Arctic (e.g., Stirling and Derocher, 1993; World Wide Fund for Nature 2002; Derocher et al., 2004). We take particular exception to the suggestion by Derocher et al. (2004, p. 163) that polar bears will not likely survive "as a species"[5] if several computer-generated scenarios of air temperature-driven disappearance of sea-ice "by the middle of the present century" come true. The conjecture seems errant for two reasons. First, most climate models predict a complete disappearance of sea-ice over the central Arctic for only the late summer (i.e., September) while the whole Hudson Bay is always ice-free during this time regardless of the forcing by anthropogenic greenhouse gases (see for example Figs. 8 and 9 in Johannessen et al., 2004). Second, in the cited climate model projections, sea-ice at the Hudson Bay for the late winter or early spring (i.e., March) was never predicted to completely disappear by the end of this century, even under scenarios that posit greenhouse gas accumulations at rates considerably faster than currently or historically observed. In a recent multi-model study of climate projection in the Hudson Bay region, Gagnon and Gough (2005b, p. 291) concluded that "Hudson Bay is expected to remain completely ice covered in those five models by the end of this century for at least part of the year."

It should also be noted that Gough et al. (2004) had earlier reported that the observed thickening of sea-ice cover during the last few decades on the western coast of Hudson Bay was

[4] It should be noted that the tendency or trend for earlier spring sea ice break-up in WH from 1979 to 1998 pointed out by Stirling et al. (1999) is not statistically significant (with p = 0.07) under the authors' own criterion and admission. Houser and Gough (2003) was also unable to demonstrate statistical significance in the trend of timing of the spring sea ice retreat at the Hudson Strait over the full interval from 1971 through 1999; although they suggest that an earlier spring ice retreat or break-up seems clear for the data starting 1990. We argue that this new tendency may be related to the sustained positive phase for the AO circulation index since 1989 till 1995 or so (see footnote 3) and it remains to be confirmed if that the AO index might remain in that trend of high positive values or the AO variability might undergoes a shift toward the low (negative) AO-value phase as in the 1950s and 1960s. Updated results shown by Gagnon and Gough (2005a) on trends in the timing of ice break-up, although now able to claim "statistical significance" under rigorous statistical testing for James Bay and western half of Hudson Bay [though it should be noted that in several records, threshold p-value of less than 0.10, instead of the threshold of 0.05 adopted for example by Stirling et al. (1999), is now used to claim significance], point out that detecting surface air temperature trends is still sensitive to the time interval of data records (see e.g., Cohen and Barlow, 2005). Another real concern is the definition of spring ice break-up and autumn freeze-up where we are not sure if the criterion of 50% ice cover for the onset of melting and freezing seasons has been optimized for the understanding of polar bear population ecology (see Rigor et al., 2000 for other suggestions and threshold criteria). In general we wish to discourage the over reliance on statistical confidence that bypasses clear physical arguments or hypotheses (see e.g., Wunsch, 1999).

[5] However, it should not be too surprising to find somewhat contradictory or more restrictive statements by these same authors from what we faithfully quoted about polar bears facing extinction in the Arctic by Derocher et al. (2004). For example, Dr. Ian Stirling was quoted in WWF (2002) to have said that "For every week earlier that break-up occurs in the Hudson Bay, bears will come ashore roughly 10 kg lighter and thus in poorer condition. With reproductive success tied closely to body condition, if temperatures continue to rise in response to increases in greenhouse gas emissions and the sea ice melts for longer periods, polar bear numbers will be reduced in the southern portions of their range and may even become *locally* [emphasis added] extinct." (p. 5).

in direct contradiction to the thinning ice scenario that is posited by warming due to an enhanced CO_2 atmosphere. Under these CO_2-warming scenarios, the models predicted not only an earlier spring break-up of sea-ice but also later fall freeze-up at Hudson Bay (Gagnon and Gough, 2005b). Available observations from 1971 to 2003, by contrast, do not show any tendency for a later freeze-up of ice especially at WH or southwestern Hudson Bay (Stirling et al., 1999; Gagnon and Gough, 2005a). Further to the north, Melling (2002, pp. 2–18), in his study of sea-ice around the northern Canadian Arctic archipelago, concluded that "[i]nterannual fluctuations in late-summer ice coverage obscure any evidence of trend [in the Sverdrup Basin]. A decadal cycle contributes variability to the times series of both total and multiyear ice concentrations. Because the reputedly extreme conditions of 1998 are similar to occurrences in 1962 and 1971, there is little basis on which to view them as evidence for anthropogenic change."

We therefore conclude that it is highly premature to argue for the extinction of polar bear across the circumpolar Arctic within this century as incorrectly suggested in Derocher et al. (2004).

Finally, we wish to encourage a renewed archaeological search for information related to polar bear population ecology from 1760 to 1820, when historical evidence (based on early thermometers at trading posts of Churchill Factory and York Factory) suggests that the climatic regimes at WH had shifted from temperate to arctic conditions (see Ball, 1995; Catchpole, 1995). Ball (1983, 1986) documented large changes and abrupt shifts in both floral (i.e., treeline boundary between the boreal forest and the tundra) and fauna (i.e., migration of wild geese) ecosystem responses of the Hudson Bay region that occurred naturally as a consequence of the varying mean locations of the Arctic Front (Bryson, 1966). Ball (1995) suggested that the three consecutive decades from 1770 to 1800 at York Factory consisted of very wet and variable winter conditions oscillating between extremes of heavy snow versus almost snow-free conditions, which made the thriving of wildlife populations difficult. Heavy late winter rains, for example, have been proposed as a cause of the collapse of maternity dens, suffocating the occupants (Stirling and Derocher, 1993). Excessive snowfall was noted to alter oxygen flux through the snow layer of maternity dens and could negatively impacting survival rates of young altricial cubs that need to be nursed for 3 months before they are able to leave the den with their mothers (Derocher et al., 2004). The records compiled by Ball and Kingsley (1984) suggested an interval with a relatively warm late spring (April–May–June) at York Factory of about 2.9 °C for 1779, 1780, and 1782 (no data for 1781) when monthly air temperature readings were available from the Hudson Bay's Company and Royal Society's archives. These data may be applied to assess the resiliency of polar bears under adverse climate conditions. The latest research by Scott and Stirling (2002) have successfully dated, through sophisticated timing and fingerprinting techniques of dendro-sciences, polar bear maternity dens and dens activities inland from the coast of WH, south of Churchill and north of York Factory, since at least 1795, while reports of polar bears have been recorded at least since 1619. These authors concluded that "there does not appear to be a relationship between climate trends and the rates of den disturbance during the overall 1850–1993 period" and that "changes in the frequency and pattern of disturbances at den sites may be related to the pattern of hunting and trading of hides at York Factory during the 19th and early 20th century" (p. 163). Thus, the reality of human activity impacting population ecology of polar bears at WH is clear while empirical evidence for polar bear resiliency under extended records of weather extremes and a wide range of climatic conditions may be stronger than previously thought.

6. Conclusions

The interactions among sea-ice, atmospheric and oceanic circulations, and air and sea temperatures are complex and our understanding of these issues in the Arctic context is limited. We suggest that large interannual variability, which we view as stochastic in nature (e.g., Wunsch, 1999), dominates the climatic changes in WH. Improved understanding of polar bear resiliency and adaptive strategy to climatic changes must consider human–bear interactions, natural population dynamics, and the dominant components of variability of the Arctic ice, ocean and atmosphere that operate naturally on decadal to multidecadal timescales (Vinje, 2001; Polyakov et al., 2003a,b; Soon, 2005). The clear evidence for strong regional differences in the spatial pattern of historical climate change around the Hudson Bay region add a layer of uncertainty to the task of explaining empirical evidence. It is certainly premature, if not impossible, to tie recent regional climatic variability in this part of central Canada to anthropogenic greenhouse gases and, further, to extrapolate species-level conditions on this basis. These complex interactions of man-made and natural factors will ultimately bring about particular ecosystem responses (perhaps yet unintelligible to us) but we find that late spring air temperature has not emerged as a decisive causal factor or reliable predictor. Such a complexity within the Hudson Bay's ecosystem clearly challenges the usefulness of the original proposal in considering polar bears as indicators of climatic warming made by Stirling and Derocher (1993).

The broad claim for the sea-ice to be "gone by the middle of the present century" could be both misleading and confusing in that existing model predictions are for the complete disappearance of late summer, rather than spring, sea-ice over the central Arctic ocean. Climate models actually expected Hudson Bay to be fully covered with sea-ice at least part of the year (including early spring) even under rather extreme forcing assumptions by involving rapid increases in anthropogenic greenhouse gases by the end of this century. This is why extrapolation studies arguing for severe negative impacts of polar bears under a global warming scenario are neither scientifically convincing nor appropriate.

The fate of the charismatic polar bear population is of considerable public concern, and rightly so. Science can best contribute to the goals of conservation by providing the most accurate possible understanding of the factors affecting the population ecology of these impressive animals. Our concern in this paper is that if attention is inappropriately confined to a single mechanism, namely greenhouse warming, opportunities to understand other relevant mechanisms behind changes in bear population and health parameters may be lost in the process. It is also abundantly clear that relying on such a strict single-variable-driven scenarios of global warming by increasing atmospheric carbon dioxide and related melting sea-ice in discussing an issue as complex as the population and well being of polar bears runs counter to the underlying realities and challenges of ecological complexity that emphasizes at least the six co-dimensions of spatial, temporal, structural, process, behavioural and geometric complexities (as e.g., outlined in viewpoints of Li, 2004; Loehle, 2004; Cadenasso et al., 2006).

Therefore, we believe it is premature to make the "one-dimensional" predictions about how climate change may affect polar bears in general and there is no ground for raising public alarm about any imminent extinction of Arctic polar bears. The multiple known and likely stresses interact dynamically and may contribute in an additive fashion to negative effects on polar bears. To quantify the severity of these stress co-factors, however, is very difficult, if not almost impossible, with current limitations on data. Areas of research we would particularly encourage include archaeological investigations, improved data on prey population dynamics, and examination of lower trophic levels to provide more insight into the proximate effects of climate change on Arctic species. We further suggest that the AO circulation index may be useful in tracking the propagation of climatic and meteorological signals through the coupled ecosystems of the Arctic land and sea that promises only the undeniable complexity of multi-trophic level interactions (Fortier et al., 1996; Steinke et al., 2002; Hansen et al., 2003).

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Is the Earth still recovering from the "Little Ice Age"? A possible cause of global warming

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Abstract

There seems to be a roughly linear increase of the temperature from about 1800, or even much earlier, to the present. This warming trend is likely to be a natural change; a rapid increase of CO_2 began in about 1940. This trend should be subtracted from the temperature data during the last 100 years. Thus, there is a possibility that only a fraction of the present warming trend may be attributed to the greenhouse effect resulting from human activities. This conclusion is contrary to the IPCC (2007) Report, which states that "most" of the present warming is due to the greenhouse effect. One possible cause of the linear increase may be that the Earth is still recovering from the Little Ice Age. It is urgent that natural changes be correctly identified and removed accurately from the presently on-going changes in order to find the contribution of the greenhouse effect.

1. Introduction

There are many documents that suggest that the period between 1500 and 1900 was relatively cool, at least in Europe; the River Thames was frequently frozen in 1676 and in the later part of the 17th century (Lamb, 1982). Stories of the exploration of the Northwest Passage also hint that sea ice conditions in northern Canada in the latter part of the 1800s were much worse than conditions today. It is now possible to cruise the passage without much assistance by icebreakers. Although there is some doubt about the exact timing of the "Little Ice Age," it is possible to infer that the period between 1500 and 1900 was relatively cool in many parts of the world, including Alaska (cf. Lamb, 1982; Gribbin (ed.), 1978; Crowley and North, 1991; Burroughs, 2001; Serreze and Barry, 2005).

Climate change during the last 100 years or so has been intensely discussed over the last few decades. However, it is important to recognize that as far as the *basic* global warming data for this period are concerned, all we have is what is illustrated in the top of the diagram of Figure 1. The IPCC Reports state that the global average temperature increased about 0.6°C (~1°F) during the last 100 years. Their interpretation may be illustrated in the second diagram of Figure 1. Certainly, both the temperature and the amount of CO_2 in the air have increased during the last 100 years or so. Further, it is well known that CO_2 causes the greenhouse effect; therefore, it is natural to hypothesize that CO_2 is a cause of the present warming trend.

However, there is so far no definitive proof that "most" of the present warming is due to the greenhouse effect, as is stated in the recently published IPCC Report (2007). In fact, the relationship between air temperature and CO_2 is not simple. For example, the temperature had a cooling trend from 1940 to about 1975, in spite of the fact that atmospheric CO_2 began to increase rapidly in about 1940, as can be seen in Figure 1.

In this note, it is pointed out that it is not possible to determine the percentage contribution of the greenhouse effect that is a direct result of human activities, unless natural causes can be identified and subtracted from the present warming trend.

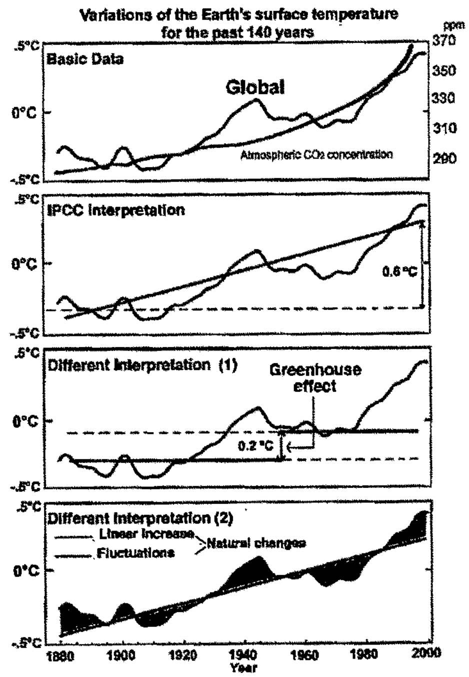

Figure 1: From the top, the basic data on global warming: the IPCC interpretation (indicating that the 0.6°C increase is caused by the greenhouse effect), another interpretation, suggesting a baseline change of 0.2°C/100 years and additional fluctuations, and yet another interpretation, a linear natural change superposed by natural fluctuations.

Actually, there are many other ways to interpret the temperature changes than what is shown in the second diagram of Figure 1. For example, the third diagram shows another interpretation. In this interpretation, it is assumed that there was a base increase of about 0.2°C during the last 100 years, which was superposed by fluctuations, such as multi-decadal oscillations. The fourth diagram shows yet another interpretation. In this interpretation, there was an almost linear increase of natural temperature change during the last 100 years, which is superposed by fluctuations, such as multi-decadal oscillations. The difference between the second and fourth diagrams is that the IPCC Report assumes that the warming trend is *mostly* due to human activities, while the latter assumes that a large fraction of the warming trend is caused by natural causes.

It is somewhat surprising that there has, so far, been no debate on such, and many other possibilities. Indeed, it is doubtful that the IPCC conclusion of "most" is the consensus of 250 experts in climatology. The greenhouse effect is a hypothesis to be proven quantitatively. Further, even if proven qualitatively, it is necessary to investigate, quantitatively, how large its effect is. At this stage in the development of modeling and simulation, one can test the hypothesis only qualitatively, not quantitatively, because there are too many uncertain parameters in the modelings. This point will be discussed later.

Figure 2 shows both the global average temperature and the temperature from stations widely distributed along the coast of the Arctic Ocean (Polyakov et al., 2002) during the last 100 years or so. One can see that the magnitude of temperature changes is significantly larger in the Arctic. A similar result was shown in the ACIA Report (2004); see p. 23. In particular, fluctuations, including multi-decadal oscillations, are greatly "amplified" in the Arctic. There occurred two major fluctuations, one between 1910 and 1975, and one after 1975. The arctic data indicates that the two fluctuations in the global average data should not be treated as minor fluctuations to be ignored. Indeed, it is crucial to investigate the nature of the temperature rise between 1910-1940 and also the one after 1975. As the top diagram in Figure 1 shows, CO_2 in the atmosphere began to increase rapidly after 1940, when the temperature decreased from 1940 to 1975. Thus, the large fluctuation between 1910 and 1975 can be considered to be a natural change. Therefore, unless the difference between the two changes can be understood, it is not possible to say tacitly that the rise after 1975 is mostly caused by the greenhouse effect.

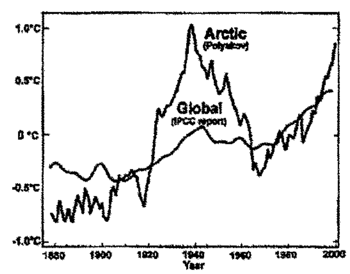

Figure 2: Red – global average change (IPCC Reports). Blue – data from stations along the coastline of the Arctic Ocean (Polyakov, et al., 2002.)

In this note, we examine first the possibility of the last case in Figure 1 and then the nature of the fluctuations.

2. Linear Increase

The basis for drawing a linear line, in the last diagram in Figure 1, is weak without additional data. Fortunately, Frizsche et al. (2006) obtained ice cores from Severnaya Zemlya, an island in the Arctic Ocean, and made the O(18) analysis. Their results are reproduced here as Figure 3. It shows the O(18) data at the top: It is possible to observe that an almost linear change is evident from about 1800 to the present in the ice core record; the red linear line is drawn by the present author; large fluctuations are also indicated as "natural changes" also by the author, since it is unlikely that CO_2 caused any major temperature fluctuations before 1940.

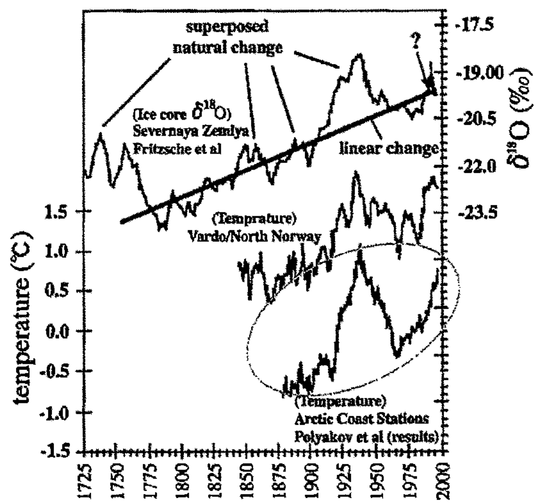

Figure 3: Late Halocene ice core record from Akademii Nauk Ice Cap, Severnaya Zemlya, Russian Arctic, together with temperature records at Vardo, Norway, and along the artic coast stations (Polyakov et aL, 2002), the last one is the same as that in Figure 2 (blue).

Their figure shows also a thermometer record from Vardo in Northern Norway. The bottom diagram is the same as the "Arctic" one of Figure 2. The credibility of the ice core record is supported by the similarity with the Norwegian temperature record and the data by Polyakov et al. (2002), or vice versa.

The ACIA Report (2004) took the *average* of 100-year records as the baseline (their figure on page 23), namely, a line parallel to the horizontal axis, with the average value as the zero line. However, the ice-core record shows that such a practice may not be appropriate. There is clearly a linear increase of temperature from about 1800. Similar linear trends can be inferred in the Norwegian data and the data by Polyakov et al. (2002) in Figure 3 based on the core record. There are several other supporting studies that suggest that there has been a linear change from about 1800 or earlier. For example, Figures 4, 5, 6, and 7 suggest a roughly linear change of temperature from the earliest recordings by Burroughs (2001), Tarand and Nordli (2001), and van Egelen et al. (2001).

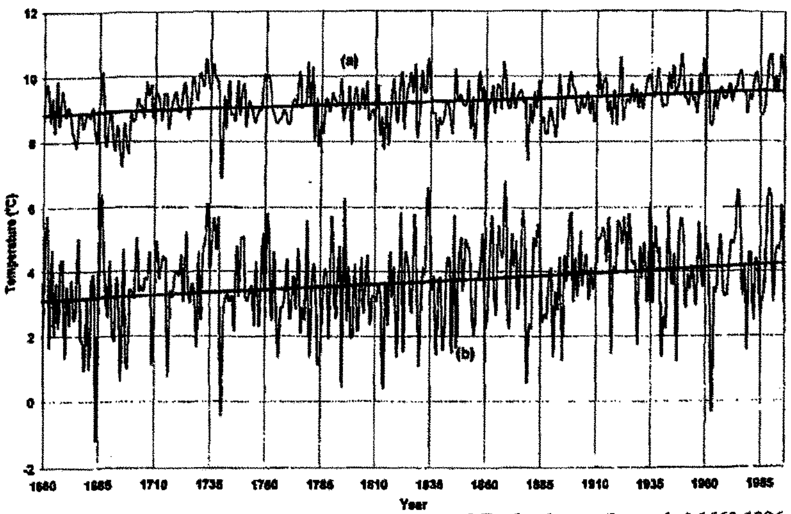

Figure 4: The linear trends for the temperature of central England over the period 1660-1996 for (a) the annual data, and (b) the winter months (December to February), show a marked warming. In both cases, this warming is significant, but although the temperature rise is greater in winter, this trend is less significant because the variance from year to year is correspondingly greater (Burroughs, 2001).

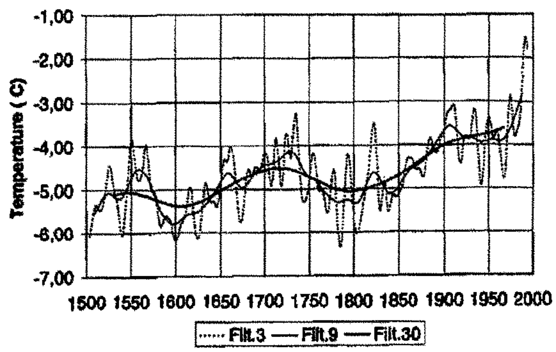

Figure 5: Winter temperature (December-March) at Tallinn since 1500, which are based on ice break-up dates in Tallinn port. The series is smoothed by Gaussian filters of 3, 9, and 30 years as standard deviations in the Gaussian distribution (Tarand and Nordli, 2001).

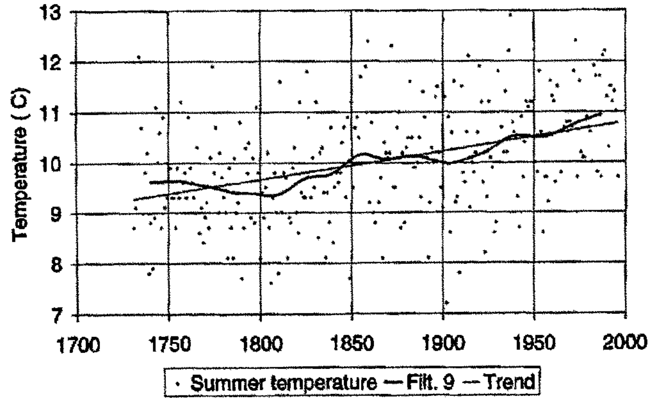

Figure 6: Summer temperature (April to July) for Tallinn, which is based on ice break-up and rye harvest data and of instrumental observations. To ease the study of variations on a timescale of approximately 30 hours, the observations are smoothed by a Gaussian filter with standard deviation of 9 years in its distribution (curve). A trend line for the whole period is also shown; Tarand and Nordli (2001)

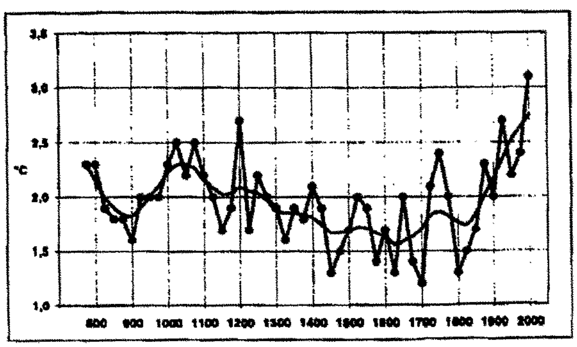

Figure 7: 25-year mean winter (DJF) temperature at De Bilt; van Egelen, Buisman and Ijnsen (2001). This figure includes a longer period data than Figures 4, 5, and 6.

There is further supporting evidence of a continuous climate change from about 1800. Figure 8 shows that the southern edge of sea ice in the Norwegian Sea has been continuously receding from about 1800. Figure 9 shows examples of glaciers in Greenland and Alaska, which have been receding from the time of the earliest records (about 1800 for Greenland and 1900 for Alaska). There are a large number of similar records from the European Alps and elsewhere (Grove, 1982). Therefore, it can be assumed that many glaciers advanced during the Little Ice

Age and have been receding since then. Thus, the retreat is not something that happened only in recent years.

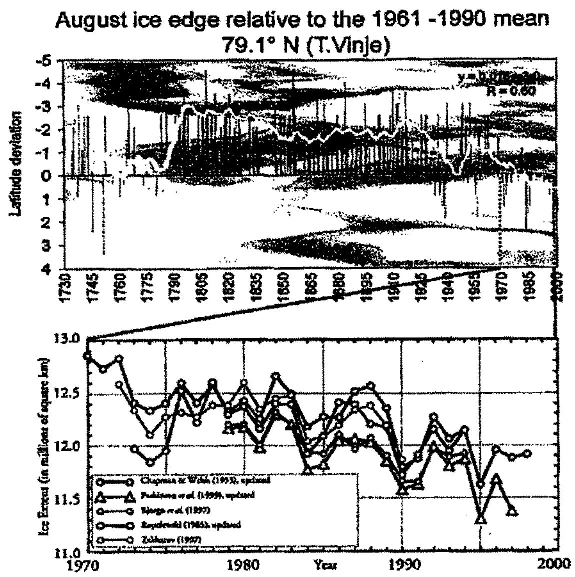

Figure 8: Retreat of sea ice in the Norwegian Sea (Vinje, 2001).

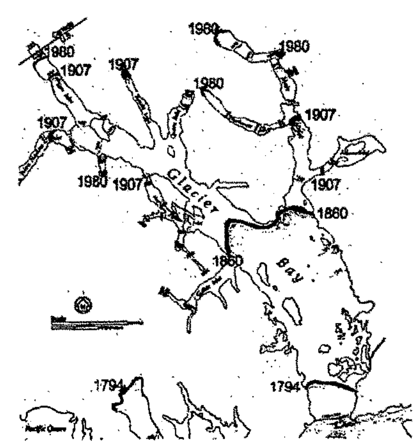

Figure 9: Retreat of glaciers in Glacier Bay (Alaska Geographic, 1993)

The fact that an almost linear change has been progressing, without a distinct change of slope, from as early as 1800 or even earlier (about 1660, even before the Industrial Revolution), suggests that the linear change is natural change. As shown at the top diagram of Figure 1, a rapid increase of CO_2 began only after 1940.

As far as the gradient of the linear change is concerned, it can roughly be estimated to be about 0.5°C/100 years based on Figures 3, 4, 5, 6, and 7. *It is very interesting to recognize that this gradient is almost comparable with the IPCC's estimate of 0.6°C/100 years.* Since the maximum decrease of temperature during the Little Ice Age is estimated to be about 0.5°C (Wilson et al, 2000) – 1.5°C (Crowley and North, 1991; Grove, 2005), it is worthwhile to speculate that the Earth is still recovering from it. Another possible additional cause may be changes in solar output (cf. Scafetta and West, 2006), which we did not investigate in this note.

Therefore, the linear change, which is likely to be a natural change, should be subtracted from the top diagram of Figure 1 in order to identify and estimate the greenhouse effect.

However, this note is not intended to evaluate an accurate estimate of the gradient of the linear change. There is a great uncertainty in obtaining early data corresponding to the accuracy of the top of Figure 1 in terms of the geographic distribution of the stations, seasons, etc. Here, I emphasize only that a significant part of the 0.6°C increase includes natural changes, contrary to the statement by the IPCC Report (2007).

At this point, we encounter one of the fundamental problems in climatology and also meteorology. Is there any definitive evidence to conclude that the Little Ice Age ended by 1900? More fundamentally, how can we determine the "normal" or "standard" temperature from which deviations (warming or cooling) are considered to be abnormal? At this time, there is no reference level to conclude that the Little Ice Age was over by about 1900.

Further, the IPCC Report (2007) states that the present high temperature is "unusual" except for about 130,000 years ago (p. 10). However, if we examine the temperatures during all the other interglacial periods (240,000, 330,000, 400,000 years ago), each period was warmer than the present one. Thus, it could be said that the present interglacial period was abnormally a cool one. In fact, even during the present interglacial period, the temperature was a little warmer than the present one for a few thousand years at its beginning (cf. Wilson et al., 2000).

3. How Linear is the Linear Change?

It is reasonable to expect that the linear change is only a rough first approximation. An accurate examination is expected to show deviations from the linear trend, if the greenhouse effect is significant, namely an upward deviation after 1940. However, this may be hard to examine because the linear change is superposed by large fluctuations.

In this respect, it is interesting to note a recent study of sea level changes (Holgate, 2006); it is shown in Figure 10. Although the data covers only the period after 1910, it is sufficient to view any indication of accelerated increase of sea level after 1940. The sea level change should reflect the expected changes associated with the thermal expansion of seawater and glacier melting changes during the last half century that were mentioned in the IPCC Reports. Figure 10 shows that there is no clear indication of an accelerated increase of sea level after 1940, even if some individual glaciers in the world show accelerated receding.

As will be discussed in the next section, the most prominent warming during the last half of the last century has ceased during the last twenty years. In this connection, it might be added that both seawater (Lynn et al., 2006) and permafrost temperatures (Richter-Menge et al., 2006), as well as the amount of CH_4, have ceased to increase from about 2000. It is puzzling why they do not show an accelerated increase if their increase before 2000 was due to the greenhouse effect; they may be temporal fluctuations.

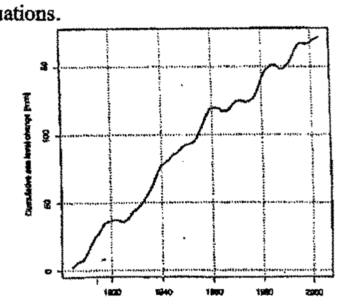

Figure 10: The mean sea level record from the nine tide gauges over the period 1904-2003 based on the decadal trend values for 1907-1999. The sea level curve here is the integral of the rates; (Holgate, 2007).

4. Fluctuations

As shown in Figure 2, two prominent fluctuations occurred during the last 100 years. The first one was a temperature rise from 1910 to 1940 and the subsequent decrease from 1940 to about 1975 (Figures 1 and 2). The second one is the present rise after 1975. As stated earlier, it is crucial to examine if both rises are due to the same, similar, or entirely different causes. Until some study can provide convincing results on this problem, we should not claim that the rise after 1975 is mostly due to the greenhouse effect.

It is interesting to note from the original paper from Jones (1987, 1994) that the first temperature change from 1910 to 1975 occurred only in the Northern Hemisphere. Further, it occurred in high latitudes above 50° in latitude (Serreze and Francis, 2006). The present rise after 1975 is also confined to the Northern Hemisphere, and is not apparent in the Southern Hemisphere; there may be a problem due to the lack of stations in the Southern Hemisphere, but the Antarctic shows a cooling trend during 1986-2005 (Hansen, 2006).

Thus, it is not accurate to claim that the two changes are a truly *global* phenomenon, even if *averaging* the data from both hemispheres can provide Figure 1. Since the greenhouse effect is supposed to be global, the two prominent changes may be considered to be regional changes. Thus, there is a possibility that both increases are natural changes, unless it can be shown definitely that such regional changes are caused by the greenhouse effect.

If so, it may not be very difficult, after all, to remove the two prominent fluctuations from the changes during the last 100 years. As a *very rough* first approximation, fluctuations above and below the linear change can also be regarded as natural changes.

It is important to note that the present global warming after 1975 is not uniform over the Earth. Although a single number, namely +0.6°C/100 years, is used in discussing global warming, the geographic distribution of "warming" is quite complex. The upper part of Figure 11 shows the "warming" pattern during the last half of the last century, from about 1950 to about 2000 (Hansen et al., 2005). One can see that the most prominent change occurred in Siberia, Alaska, and Canada, namely in the continental arctic. In the continental arctic, the warming rate was several times more than the global average of 0.6°C/100 years (0.6°C/2=0.3°C/50 years). It may be also noted that cooling was in progress in Greenland over the same time period.

It is of great interest to ask if GCMs can reproduce this geographic distribution of the observed changes shown in the upper part of Figure 11. Thus, we asked the IPCC arctic group (consisting of 14 sub-groups headed by V. Kattsov) to "hindcast" geographic distribution of the temperature change during the last half of the last century. To "hindcast" means to ask whether a model can produce results that match the known observations of the past; if a model can do this, we can be much more confident that the model is reliable for predicting future conditions Their results are compiled by Bill Chapman, of the University of Illinois, and are shown in the right side of Figure 12. The left side of the figure is taken from the ACIA Report (2004), which shows a similar trend as that of the upper part of Figure 11, namely the prominent warming in the continental arctic and cooling in Greenland. This comparison was undertaken to reduce differences between them, because both are expected to be imperfect.

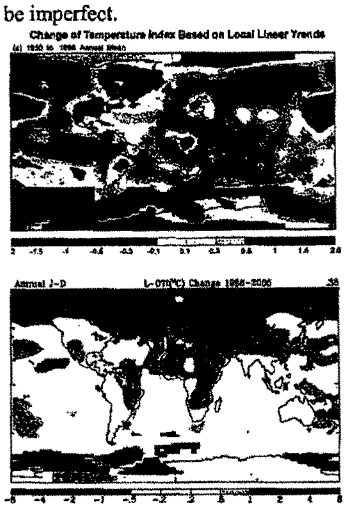

Figure 11: Upper – the geographic distribution of temperature change between 1950 and 1998 (Hansen et al., 2005). Lower – the geographic distribution of temperature change between 1986 and 2005 (Hansen, 2006).

We were surprised at the difference between the two diagrams in Figure 12. If both were reasonably accurate, they should look alike. Ideally, the pattern of change modeled by the GCMs should be identical or very similar to the pattern seen in the measured data. We assumed that the present GCMs would reproduce the observed pattern with at least reasonable fidelity. However, we found that there was no resemblance at all.

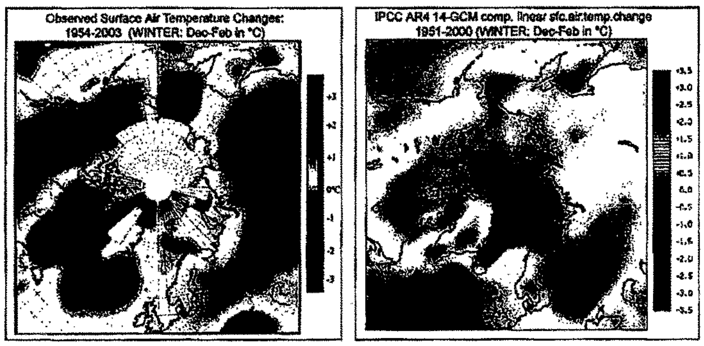

Figure 12: Comparison of the observed distribution of temperature changes (ACIA, 2004) and the simulation ("hindcasting") by the IPCC arctic group.

Our first reaction to this surprising result was that GCMs are still not advanced enough for hindcasting. However, this possibility is inconceivable, because the increase of CO_2 measured in the past is correctly used in the hindcasting, and everything we know is included in the computation. The IPCC arctic group's result is the best result that is possible based on our present knowledge. If the greenhouse effect caused the warming, it should be reproducible to some extent by these models, even if the reproduction is not perfect. It took a week or so before we began to realize another possibility of this discrepancy: If 14 GCMs cannot reproduce prominent warming in the continental arctic, perhaps much of this warming is not caused by the greenhouse effect at all. That is to say, because it is not caused by the greenhouse effect, the warming of the continental arctic cannot be reproduced by our GCMs. How do we examine that possibility?

If the prominent warming in the continental arctic is due to the greenhouse effect, the prominent trend should continue after 2000. That is, we should observe an amplification of continental arctic warming in this century that will be even greater than the amplification that was observed during the last half of the last century, because the amount of CO_2 continues to increase at an exponential rate. Thus, we examined the warming trend during just the last 20 years or so, provided by Hansen (2006). To our surprise, the prominent continental arctic warming almost disappeared in those results; the Arctic warmed at a rate about like that of the rest of the world, while Greenland showed a strong warming (the lower part of Figure 11). Actually, the temperature shows a cooling trend in Fairbanks between 1977 and 2001 (Hartman and Wendler, 2005). Therefore, our conclusion at the present time is that much of the prominent continental arctic warming and cooling in Greenland during the last half of the last century is due to natural change, perhaps to multi-decadal oscillations like Arctic Oscillation, the Pacific Decadal Oscillation, and the El Niño – Southern Oscillation. This trend is shown at the bottom of Figure 1 as positive and negative fluctuations.

5. Summary

From the data provided in the earlier sections, it is quite obvious that the temperature change during the last 100 years or so includes significant natural changes, both the linear change and fluctuations. It is very puzzling that the IPCC Reports state that it is mostly due to the greenhouse effect Radiative and other forcings are considered to explain the present warming of 0.6°C/100 years, so that they cannot be a confirmation of the term "most." Further, unfortunately, computers are already incorrectly "taught" that the 0.6°C rise during the last hundred years was caused by the greenhouse effect, so they cannot prove the greenhouse effect and cannot predict accurately the degree of future warming.

It is suggested here that the linear change may be due to the fact that the Earth is slowly recovering from the Little Ice Age, although the cause of the Little Ice Age is unknown at the present time.

It is urgent that natural changes should be correctly identified and removed accurately from the present on-going changes in order to find the contribution of the greenhouse effect. Only then will an accurate prediction of future temperature changes become possible.

One lesson here is that it is not possible to study climate change without long-term data. This is understandable from the fact that it is not possible to draw the linear line in the fourth diagram of Figure 1 without the data shown in Figures 3, 4, 5, 6, 7, and 8. It is very easy to discredit the results of the traditional climate change studies (Figures 4, 5, 6, and 7) in terms of accuracy. However, this is what climatologists must face. In some sense, inaccurate data during the last few hundred years are more important than accurate satellite data after 1970 in our study of global warming. Unfortunately, at this time, many studies are focused on climate change after 1975, because satellite data have become readily available. A study of climate change based on satellite data is a sort of "instant" climatology.

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APPENDIX C

APPENDIX C

A. Existing Regulatory Mechanisms

1. The proposed listing did not adequately consider existing regulatory mechanisms regarding polar bear conservation.

a. United States-Russia Polar Bear Conservation and Management Act of 2006

On January 12, 2007, H.R. 5946 was signed into law as Public Law 109-479. Sections 901 and 902 of the Public Law, titled the United States-Russia Polar Bear Conservation and Management Act of 2006 (Act), amended the Marine Mammal Protection Act (MMPA) to make it unlawful for a person subject to, or in waters or on lands under, United States jurisdiction to take, import, export, possess, transport, or sell any polar bear or polar bear products in violation of the *Agreement Between the Government of the United States of America and the Government of the Russian Federation on the Conservation and Management of the Alaska-Chukotka Polar Bear Population* (Agreement) or any annual taking limit or other restriction adopted by the United States-Russia Polar Bear Commission.

The Act then sets forth requirements for designation and appointment of the United States members on the United States-Russia Polar Bear Commission, and requires the Secretary of the Interior to take all necessary actions to implement the decisions and determinations of the United States-Russia Polar Bear Commission. MMPA § 507. The Secretary of the Interior is also required to administer and enforce the Agreement on behalf of the United States, and to share authority for the management of the taking of polar bears for subsistence purposes with the Alaska Nanuuq Commission. MMPA §§ 503, 504.

As noted by the IUCN/SSC Polar Bear Specialist Group's 2005 Report, the principal threat to the Chukchi Sea polar bear population was unsustainable harvest levels in the absence of implementation of the United States-Russia treaty. Due to the enactment of H.R. 5946, the treaty is now ratified and in effect, and sets in place sufficient regulatory mechanisms to address the most significant threat to the Chukchi Sea population.

The Act also addresses poaching of polar bear by authorizing a government official to import a polar bear or a polar bear product for purposes of forensic testing or any other law enforcement purpose. MMPA § 502(b). Additionally, any polar bear or any part or product of a polar bear taken, imported, exported, possessed, transported, sold, received, acquired, purchased, exchanged, or bartered, or offered for sale or exchange in violation of this title is subject to seizure and forfeiture, without any showing that may be required for assessment of a civil penalty or for criminal prosecution. MMPA § 503(c).

The proposed rule listing the polar bear under the ESA is very dismissive of the Agreement, noting that the Act "provides the necessary authority to regulate and manage the harvest of polar bears from the Chukchi Sea population, <u>an essential conservation measure</u>" but faulting the Act because "the Act does not provide authority or mechanisms to address ongoing loss of sea ice." 72 Fed. Reg. at 1087 (emphasis added). Contrary to USFWS's characterization, the Agreement requires that the United States and Russia adopt habitat conservation measures. Specifically, in Article IV, the Agreement states:

> The Contracting Parties shall undertake *all efforts necessary* to conserve polar bear habitats, with particular attention to denning areas and *areas of concentration of polar bears during feeding and migration.* To this end, they shall take steps necessary to prevent loss or degradation of such habitats that results in, or is likely to result in, mortality to polar bears or reduced productivity or long-term decline in the Alaska-Chukotka polar bear population.

(Emphasis added). These habitat protection requirements are adopted by the recent MMPA amendment which requires that the Secretary "do all things necessary and appropriate . . . to implement, enforce, and administer the provisions of the Agreement. . . ." MMPA § 503(a). This is a significant agreement which restricts harvesting and hunting of polar bear and commits both parties to the conservation of ecosystems and habitats. USFWS should recognize the Agreement as an existing regulatory mechanism to conserve the species, with the potential to help prevent the risk of extinction for polar bear.

b. The Alaska Nanuuq Commission

The Alaska Nanuuq Commission (ANC) was formed in 1994 to represent the villages in North and Northwest Alaska on matters concerning the conservation and sustainable subsistence use of polar bear. The tribal council of each member village passed a resolution to become a member, and to authorize the ANC to represent them on matters concerning polar bear at regional and international levels. In 2001, the ANC signed a co-management agreement with USFWS. The co-management agreement authorizes ANC to work on six major areas: 1) enter into co-management agreements; 2) participate in the Joint Commission under the United Stats/Russia Treaty regarding polar bear harvest; 3) document Traditional Knowledge of Polar Bear Cultural Values and Utilization practices in Alaska; 4) participate in, and facilitate the North Slope Polar Bear Studies Plan; 5) participate and facilitate the Strategic Plan for the Conservation, Management, and Research of Alaska Polar Bear Populations; and 6) provide for conservation, education and outreach.

In reviewing existing regulatory mechanisms, the proposed rule fails to recognize the benefits provided by the ANC, and the potential for the ANC to provide additional conservation mechanisms if required to assist in polar bear conservation.

c. Inuvialuit-Inupiat Polar Bear Management Agreement in the Southern Beaufort Sea

While passage of the MMPA in 1972 banned polar bear hunting unless done by Alaska Natives for subsistence, the MMPA placed no restrictions on the numbers or composition of the subsistence hunt, leaving open the potential for an overharvest with no legal management response until the population was declared depleted. Recognizing that as a threat to the conservation of the shared polar bear population, the Inuvialuit Game Council from Canada and the North Slope Borough from Alaska negotiated and signed a user-to-user agreement, the "Polar Bear Management Agreement for the Southern Beaufort Sea" in 1988. The 1988 Agreement provides for: protection of cubs and their mothers and denning females; restrictions on hunting seasons; allocation guidelines; prohibitions on the use of aircraft or large motorized vessels to take polar bears; protection of the environment; and continued support for polar bear research and data acquisition.

In a review of the 1988 Agreement, the consensus was that it has been successful because both the total harvest and the proportion of females in the harvest have been contained within sustainable limits. While noting that harvest monitoring needs to be improved in Alaska, and awareness of the need to prevent overharvest of females needs to be increased in both countries, it was concluded that the 1988 Agreement is a useful model for other user-to-user conservation agreements. *See* C.D. Brower, et. al., "The Polar Bear Management Agreement for the Southern Beaufort Sea: An Evaluation of the First Ten Years of a Unique Conservation Agreement" (May 2001). The ability for this existing regulatory mechanism to provide for the conservation of polar bear should be noted by USFWS in its ruling on the proposed listing. Because user-to-user conservation agreements have a history of working in Alaska, the 1998 Agreement provides yet another existing regulatory mechanism and potential avenue for polar bear conservation besides listing the species under the ESA.

2. *The proposed listing did not adequately review existing local, state and international mechanisms designed expressly to reduce human causes of climate change (identified by USFWS as having a significant impacting on sea ice).*

Climate change has been identified by USFWS as a major contributor to sea ice habitat changes. 72 Fed. Reg. at 1071. There is no evidence that in the proposed rule USFWS considered recently adopted or strengthened local, state or international initiatives designed to reduce the man-made causes of climate change which contribute to warming in the Arctic, impacting sea ice, which in turn is cited as the primary factor for the determination that polar bear are a threatened species. 72 Fed. Reg. at 1082. The proposed rule contains incomplete information on existing regulatory systems and mechanisms to address climate change.

a. International Regulatory Systems and Mechanisms

i. Arctic Council

The impact of climate change on the Arctic, and conservation of species in the Arctic, has been addressed by a high-level intergovernmental forum, the Arctic Council. The Arctic Council was formed in 1996 to ensure environmental, social and economic sustainable development in the Arctic region. Current council members include the United States, Canada, Denmark, Finland, Iceland, Norway, Russia and Sweden. Six Arctic indigenous communities are Permanent Participants on the Council. The Arctic Council has five expert working groups focusing on monitoring, assessing and providing scientific work regarding specific issues in the Arctic. The working groups which should be consulted regarding polar bear and the impact of climate change on habitat in the Arctic include: The Arctic Monitoring and Assessment Programme (which identifies pollution risks and their impact on the Arctic ecosystems and assesses the effectiveness of international agreements on pollution control); the Protection of the Arctic Marine Environment (which reviews climatic and developmental pressures on the Arctic marine environment from shipping, dumping, offshore oil and gas development and land-based activities); and the Conservation of Arctic Flora and Fauna (which works for enhanced monitoring of biodiversity at the circumpolar level, fully utilizing traditional knowledge, to detect the impacts of global change on biodiversity and enable Arctic communities to effectively respond and adapt to those changes).

Studies and actions by the Arctic Council should also be addressed in the proposed rule, including: the Protection of the Arctic Marine Environment workgroup's development of the Regional Programme of Action which addresses urgent pollution problems in the Arctic marine environment stemming from land-based activities and the Arctic Climate Impact Assessment, which notes the ongoing warming of the Arctic as well as possible adaptations and responses.

ii. United Nations Framework Convention on Climate Change

The proposed rule should also note international climate change policy such as the United Nations Framework Convention on Climate Change (UNFCCC), which regulates greenhouse gas emissions. 189 nations, including the United States, have ratified the UNFCCC, agreeing to the common objective of stabilizing greenhouse gas emissions "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." UNFCCC at Art. 2.

iii. Kyoto Protocol

The Kyoto Protocol is a binding addendum to the UNFCCC which requires industrialized countries that ratified the treaty to collectively reduce greenhouse gas emissions by about five percent compared to the 1990 levels between 2008 and 2012. As of December 2006, 169 countries and other government entities are party to the Kyoto Protocol.

b. State and Local Regulatory Systems and Mechanisms

i. Kyoto Protocol adopted by Cities

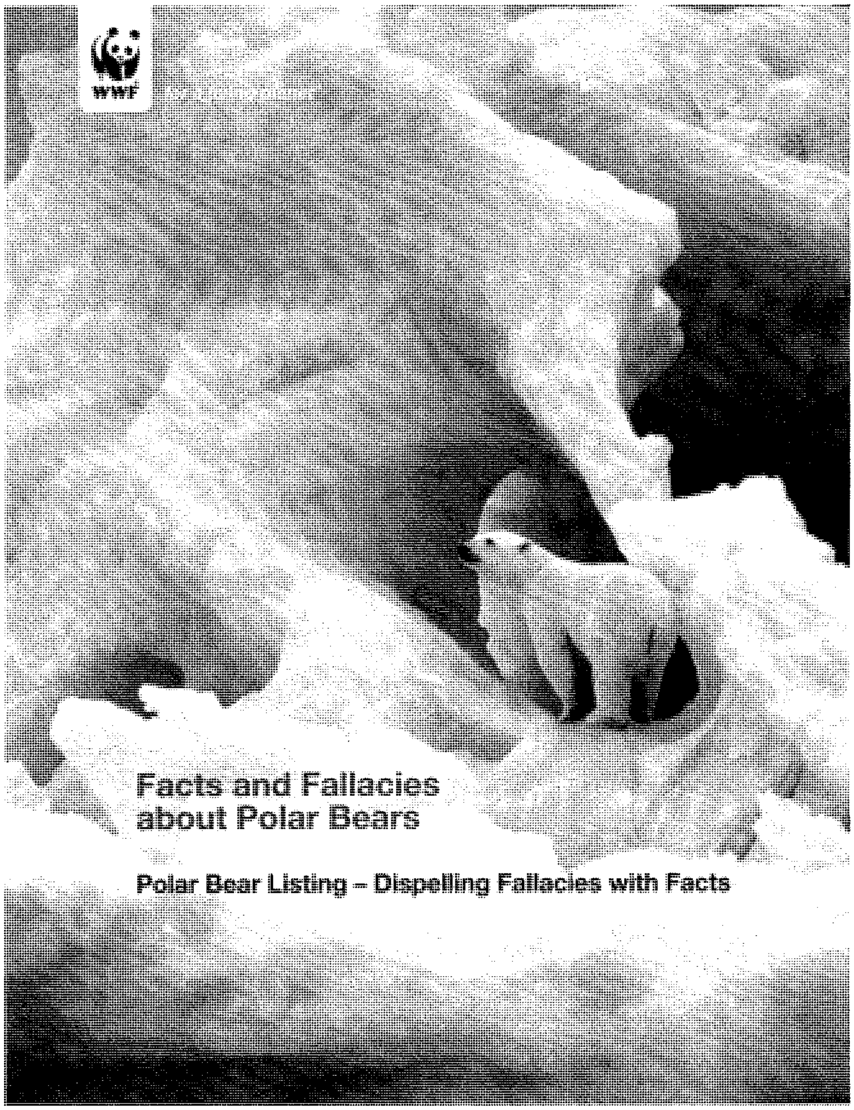
While the United States is not party to the Kyoto Protocol, 435 mayors from 50 states representing a total population of over 61 million citizens, have agreed to: meet or exceed the Kyoto Protocol targets in their own communities; urge their state governments, and the federal government, to enact policies and programs to meet or exceed the greenhouse gas emission reduction target suggested for the United States in the Kyoto Protocol - a 7% reduction from 1990 levels by 2012; and urge the U.S. Congress to pass the bipartisan greenhouse gas reduction legislation, which would establish a national emission trading system.

ii. Regional Initiatives

The Regional Greenhouse Gas Initiative began on January 18, 2007, as eight Northeastern states initiated a state level emissions capping and trading program. Participating states include: Maine, New Hampshire, Vermont, Connecticut, New York, New Jersey, Delaware, and Massachusetts. Observer states and regions include: Pennsylvania, Maryland, District of Columbia, and the Eastern Canadian Provinces. In conjunction with their individual state emission cap programs, the West Coast Governors have adopted a Western Regional Climate Change Initiative through which Washington, Oregon, California, New Mexico and Arizona will work together on climate protection.

iii. State Caps on Greenhouse Gas Emissions

On August 31, 2006, California adopted AB 32, an economy-wide cap on carbon dioxide emissions. The aim of AB 32 is to reduce the state's greenhouse-gas emissions, which rank as the 12th-largest in the world, by 25 percent by the year 2020. Several other states have adopted similar measures to reduce their contribution to global climate pollution, including Washington and Oregon.


WWF
Facts and Fallacies
about Polar Bears
Polar Bear Listing – Dispelling Fallacies with Facts

World Wildlife Fund (WWF) has worked around the world's Arctic regions for over 25 years to protect Arctic wildlife such as walrus, whales, seals and polar bears. Today, many species are facing new threats as climate change warms and alters arctic habitats. In late 2006, the U.S. Fish and Wildlife Service (USFWS) proposed listing the polar bear as threatened under the Endangered Species Act of 1973. Because there is confusion and misinformation reported about polar bears and the effects of global warming on their habitat, WWF has compiled the following facts to clarify inaccuracies from truths.

Fallacy 1:

"There are still 20,000-25,000 polar bears in the wild. That's too large a number to allow for considering the species to be endangered."

Facts:

- The Endangered Species Act (ESA) specifies that the listing of a threatened or endangered species is justifiable when any of the following criteria are met:
  1. The present or threatened destruction, modification, or curtailment of its habitat or range;
  2. Overutilization for commercial, recreational, scientific, or educational purposes;
  3. Disease or predation;
  4. The inadequacy of existing regulatory mechanisms;
  5. Other natural or manmade factors affecting its continued existence.

WWF believes that the proposal by the USFWS is based on a logical and science-based case, to which many respected experts from around the world have contributed.

- The listing of the polar bear as a threatened species is warranted chiefly because of the "threatened destruction, modification, or curtailment" of polar bear habitat or range, i.e., the sea ice. Sea ice is anticipated to decrease significantly over the next 45 years. As of December 12, 2007 NASA climate scientist Jay Zwally predicts that summer sea ice may be entirely gone by 2012.

Fallacy 2:

"The listing should be made on the current status of the bear - not on the potential, future loss of habitat."

Facts:

- The life history of polar bears is intricately tied to the Arctic sea ice. While polar bears are found in most ice-covered areas in the northern hemisphere, they appear to prefer annual sea ice in shallow, productive waters. In recent decades, sea ice has been diminishing at an unprecedented rate. In fact, records for sea ice decline were broken in August, 2007, signaling a major loss of the polar bear's most important habitat. Although 20,000-25,000 seems like a big number, experts predict that based on projections of continued sea ice decline, as early as mid-century, two-thirds of the world's polar bears could be lost.
- Under the Endangered Species Act, a threatened species is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Accordingly, USFWS is required to analyze not only the current status of a species but also its status into the foreseeable future.

Fallacy 3:
"Listing won't really help the polar bear because it won't stop the melting of sea ice."

Facts:
- The ESA was intended by Congress to provide a means to protect endangered and threatened species as well as the ecosystems on which they depend.
- Listing the polar bear under the ESA requires the federal government to take actions not available under other pertinent regulatory mechanisms for the protection of listed species. For example, if the polar bear is listed, USFWS will be required to identify and protect critical habitat for the polar bear. USFWS will also be obligated to develop a recovery plan, which provides a science-based "road map" that guide managers responsible for the species. A recovery plan should include site-specific actions, estimates of time and cost of the recommended measures and criteria for "de-listing" the species.
- Additionally, if the polar bear is listed as threatened, the federal government will be required to identify and designate "critical habitat" for the polar bear. The ESA defines "critical habitat" as "specific areas within the geographical area occupied by the species" which contain "physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection. Critical habitat can also include "specific areas outside the geographical area occupied by the species."
- In addition to these legal measures, the public discussion about listing the polar bear has attracted world-wide attention to the issue of sea ice decline and global climate change. Only through such broad awareness and engagement of the public will it be possible to reduce the production of the "greenhouse gases" that have led to the current trends in warming that we are witnessing today.

Fallacy 4:

"If polar bears are listed as threatened under the ESA in the United States, all hunting of polar bears will be stopped, and local communities will be negatively impacted."

Facts:

- For thousands of years, indigenous peoples of the Arctic have harvested marine wildlife for sustenance as well as clothing and handicrafts. In Alaska, Canada and Greenland, indigenous people harvest polar bear for subsistence purposes. In Russia, a new U.S.- Russia treaty that was legally enacted in September 2007 opens the possibility for Russian native people to conduct a harvest, pending recommendations from scientists. In the United States, Alaskan native rights to harvest marine mammals for subsistence and use in handicrafts are protected under the Marine Mammal Protection Act (MMPA). This right will not be suspended if the bear is listed.
- Currently the native harvest of polar bears in the Southern Beaufort Sea is managed by an international agreement between the Inupiat people of Alaska and the Inuvialuit people of Canada, who share a quota of polar bears. In Canada, a part of the quota is apportioned to recreational hunting permits.
- The majority of recreational hunters in Canada are U.S. citizens, and in 1994 an amendment to the MMPA was made to allow these hunters to import their legally taken trophies into the United States. If the polar bear is listed as threatened, U.S. hunters who participate in such a sport hunt will not be able to import the hide of any polar bear harvested. The MMPA prohibits sport and commercial hunting of polar bears in Alaska. Greenland allows only full-time hunters living a subsistence lifestyle to hunt polar bears.

Fallacy 5:

"Canadian scientists and governments strongly oppose the listing of polar bears under the ESA."

Facts:

- The government of the Canadian province of Nunavut and its biologists have gone on record in opposition to the listing of the polar bear as a threatened species. However, other Canadian scientists and governments support such protections as listing the polar bear as threatened. Two of the world's leading polar bear biologists, Dr. Ian Stirling and Dr. Andrew Derocher are supportive of additional protective measures for polar bear populations. The Minister of Natural Resources David Ramsay has warned that continued climate change may lead to the extinction of polar bears in southeastern Canada.
- Canada currently lists the polar bear as a "species of concern" and in April of 2008, the government will determine whether to add the polar bear to the Canadian Species at Risk Act (SARA) list, which is similar to the ESA.

Fallacy 6:

"Legislation currently in place in the United States is adequate to protect the polar bear and therefore it is not necessary for the USFWS to list the polar bear under the ESA."

Facts:

- In its proposal to list the polar bear at threatened, the USFWS acknowledges that the regulatory mechanisms directed specifically at managing immediate threats to polar bears do exist in all of the range states where the species occurs. However, polar bears are most threatened by the accelerating loss of Arctic sea ice habitat as a result of climate warming. There are no existing regulatory mechanisms requiring the conservation of sea ice habitat in the Arctic and current energy policies in the countries, China and the U.S., which are the leading polluters, are inadequate to curb greenhouse gas emissions.
- There is one avenue available to protect the principal habitat of polar bears -- the designation of "critical habitat" but this requires first listing the polar bear under the ESA.
- Other measures that are not in place, but which WWF is promoting, include an Arctic-wide treaty that would help to protect the entire range of the polar bear and would regulate other threats to the polar bear and its habitat. Also, WWF joins many other conservation organizations in promoting a global reduction of CO_2 emissions.

Fallacy 7:

"Polar bears will be able to adapt to hunt and live on land, where alternative food sources can be found."

Facts:

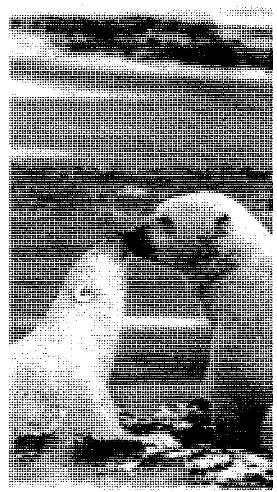
- On average, an adult polar bear needs approximately 2 kg (4.4 lbs) of seal fat per day to survive. Sufficient nutrition is critical and is stored as fat that helps polar bears survive the harsh arctic winter.
- Polar bears are carnivores, preying heavily throughout their range on ice seals, primarily ringed seals and bearded seals. Polar bears also have been known to kill much larger animals such as walruses, narwhal, and belugas.
- As the Arctic sea ice continues to decline, polar bears will have less access and time to forage on these important food sources. In the western Hudson Bay, where the ice breaks up three weeks earlier than it did 20 years ago, scientists have recorded nutritionally stressed bears and lower survival in the population.
- In some areas and under certain conditions, prey and carrion other than seals may supplement a polar bear's diet. Polar bears will eat human garbage, and when confined to land for long periods they will consume coastal marine and terrestrial plants and other terrestrial food if necessary. However, these sources are nutritionally poor compared to the high fat content of ice seals, and would not be adequate to replace the polar bears' preferred food. In addition the sea ice habitat is changing too rapidly for polar bears to evolve to a terrestrial life style. In summary, there is no scientific evidence indicating that polar bears can sufficiently adapt to a life without ice seals and maintain viable populations.

Fallacy 8:

"Polar bears survived warming periods before, and some warming may actually benefit polar bears."

Facts:

- As a species, polar bears have survived at least two warming periods in the past. For example, 6,000 to 10,000 years ago, summer temperatures were two to three degrees Celsius warmer than today. However, there were also periods (140,000 and 20,000 years ago) when temperatures were much colder - as much as 10 degrees Celsius.
- Although we do not know how polar bears survived those warming periods, we do know that the species' survival is closely dependent on Arctic sea ice, which is rapidly diminishing in much of the Arctic.
- If any warming is to benefit bears, this may be for those which occupy the northernmost regions where sea ice is present year-round. But in places where sea ice is receding, bears are forced to spend more time on land or on the remaining pack ice over the relatively deep and unproductive waters in central polar basin and thus are deprived from their key food sources for longer periods.
- Unlike past warming periods, polar bears now face additional anthropogenic threats such as pollutants and various forms of human disturbance.



Fallacy 9:

"Climate modeling is speculative and there is a lack of agreement on climate warming."

Facts:

- In the last two years, several major studies have been co-authored and peer-reviewed by hundreds of well-respected scientists that document evidence of global climate change. These experts have reached widespread agreement that:
  1. Climate change is real;
  2. Human-caused pollution is the main contributing factor and that;
  3. The Arctic is one of the regions to experience climate change most acutely.
- Observations have shown a decline in late summer Arctic sea ice extent of 7.7 percent per decade and in the perennial sea ice area of up to 9.8 percent per decade since 1978. In some places, a thinning of the Arctic sea ice of as great as 32 percent or more from the 1960's and 1970's to the 1990's has been shown. More importantly, the rate of sea ice decrease is accelerating, with record low minimum extents in the sea ice recorded in 2005 and even lower in 2007.
- One widely accepted scientific study suggests that abrupt reductions in the extent of summer ice are likely to occur over the next few decades, and that near ice-free September conditions may be reached as early as 2040. In December, 2007, Dr. Jay Zwally of NASA predicted that summer sea ice may be gone as early as 2012.
- Besides diminishing sea ice, other impacts in the Arctic that are already being observed include: shrinking glaciers, thawing permafrost, and Arctic "greening" (encroachment of shrubs and trees into tundra ecosystems) validate - and in many cases - exceed predictions made regarding temperature trends, reductions to annual sea ice during the summer and winter periods, reductions to multiyear pack ice and reductions to ice thickness.

Fallacy 10:

"Polar bears can breed with grizzly bears to avoid extinction."

Facts:

- Hybrid polar-grizzly bears are neither polar bears nor grizzly bears. Hybridization of the two bear species does not prevent one or the other from going extinct; rather it may actually facilitate extinction.

Fallacy 11:

"Polar bears can be moved --- to zoos or parks where they can be cared for, or even to Antarctica, where there is also snow and ice."

Facts:

- Although zoos can play an important role in captive breeding and reintroduction of animals into the wild, this measure would be largely impractical and over the long-term, is not likely to help polar bears survive in the wild.
- The introduction of polar bears to Antarctica is also impractical. In addition to the unlikely potential of capturing polar bears and safely transporting an entire population to the southern hemisphere, such a measure would have great potential to significantly disrupt the existing ecosystem there. For example, introducing a predator such as the polar bear could jeopardize a variety of potential prey species such as penguins and seals.

Fallacy 12:

"Artificial platforms can be built in the Arctic Ocean that may be utilized by polar bears and ice seals in place of melting sea ice."

Facts:

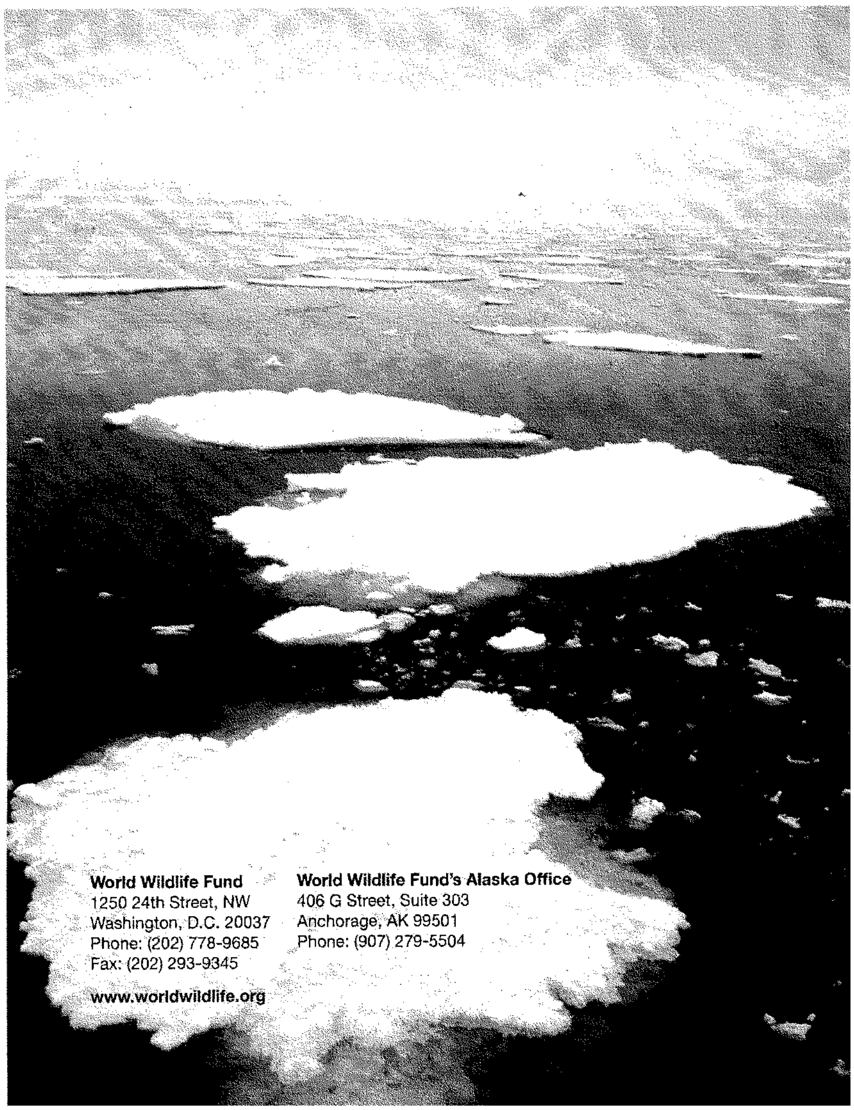
- This is a possible mitigation deserving more study; however, any such platforms would need to effectively mimic the habitat characteristics and uses that sea ice serves for polar bears and ice seals. Realistically, this is not likely to work in the harsh seas and rough weather in the Arctic.
- A fundamental fact is that polar bears catch seals, mainly at their breathing holes or birth lairs on the sea ice and seals could not make breathing holes in artificial/plastic sheeting covering thousands of km2 of arctic ocean. The arctic ecosystem that polar bears have evolved in is driven by the ice-water interface. Furthermore, WWF could not condone creating new sources of marine debris to an ocean which already suffers from pollution.

Fallacy 13:

"Oil and gas development poses no discernable threat to polar bears or their habitat."

Facts:

- The principal cause of climate change in the Arctic is global warming, which the scientific community has clearly linked to the increase of carbon dioxide into the atmosphere via human use of fossil fuels (e.g., coal, oil and gas).
- Thus, oil and gas development does indeed pose a discernable threat to sea ice and indirectly to polar bears by virtue of the extraction and development of sequestered hydrocarbons that are subsequently used by people for energy.
- Oil and gas exploration and development activities in the Arctic (e.g., Chukchi and Beaufort seas off Alaska and Canada) pose other hazards to polar bears, ice seals, and their sea ice habitats, the most notable threat being that of spilled oil which cannot be cleaned up effectively. Oiled bears and seals would likely suffer lethal and sub-lethal effects. Disturbances due to seismic exploration, construction, transportation and the operation of facilities, as well as contamination from oil spill cleanup operations, may negatively impact polar bears. Furthermore, exploration of oil and gas continues to add CO_2 into the atmosphere, which is the leading cause of the global warming and the loss of the polar bear's sea ice habitat.
- WWF urges individuals, corporations and governments to recognize the need for conservation and better use of fossil fuels in addition to the development of new cleaner air technologies to meet our ever increasing energy demands.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Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope

Committee on Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope

Board on Environmental Studies and Toxicology

Polar Research Board

Division on Earth and Life Studies

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polar bears and their habitats (FWS 1995b), no formal projections have been made of how likely effects on ringed seals or polar bears from future oil and gas activities are to accumulate with effects of other human activities. For purposes of making such a projection, the committee's scenario assumes that offshore exploration for oil and gas, and possible extraction, will occur in the Beaufort Sea from Barrow to Flaxman Island, and possibly to the Canadian border. Activity would occur mostly near shore, adjacent to onshore oil reserves, and development would entail methods and structures similar to those currently in use (gravel islands or bottom-founded structures, horizontal drilling, buried pipelines, and an emphasis on working during winter).

Full-scale industrialization of near-shore areas would most likely result in at least partial displacement of ringed seals. The frequency with which polar bears come into contact with people and structures is undoubtedly a function of the amount of activity in their habitats. Even with the best possible mitigation measures in place, it is certain that some bears will be harassed or killed. More human activity along the coast and near shore could reduce the suitability of some areas for use by denning female bears. This effect is likely to be greatest east of the Canning River, especially within the 1002 Area of the Arctic National Wildlife Refuge, where the highest concentration of on-land dens is found (Amstrup 1993, Amstrup and Gardner 1994). Efforts to identify areas where polar bears are most likely to den in the eastern part of the North Slope (Durner et al. 2001), should improve the ability of regulators and industry to reduce disturbance of denned bears.

Contact with spilled oil or other contaminants in the ocean would harm ringed seals and polar bears, and the likelihood of spills would increase with increased exploration and development. Amstrup and colleagues (2000) modeled the spread of a hypothetical 5,900 bbl (939,000 L, 248,000 gal) oil spill from the Liberty prospect[1] as it might affect the seasonal distribution and abundance of polar bears in the Beaufort Sea. The number of bears potentially affected by such a spill ranged from 0 to 25 with summer open-water conditions and 0 to 61 with autumn broken-ice conditions. In its findings permitting the oil and gas industry to take polar bears in Alaska waters, the FWS stated, "We conclude that if an oil spill were to occur during the fall or spring broken-ice periods, a significant impact to polar bears could occur" (65 Federal Register 16833 [2000]). It seems likely that an oil spill would affect ringed seals the same way the *Exxon Valdez* affected harbor seals (*Phoca vitulina*) (Frost et al. 1994a, Lowry et al. 1994, Spraker et al. 1994), and the number of animals killed would depend largely on the season and the size of the spill. Polar bears could be further affected if they ate oil-contaminated seals (St. Aubin 1990b).

Climate change also will affect marine mammals (Tynan and DeMaster 1997). Sea ice is important in the life of all marine mammals in the arctic and subarctic regions (Fay 1974). Already, there have been dramatic decreases in the extent and thickness of sea ice throughout the northern hemisphere, and those trends are expected to continue through the next century (Vinnikov et al. 1999, Weller 2000). The distribution, abundance, and productivity of Alaskan marine mammal populations will likely be altered by the combined effects of changes in physical habitats, prey populations, and interspecies interactions (Lowry 2000). Warming is likely to increase the occurrence and residence times of subarctic species (spotted seals, walrus, beluga whales, bowhead whales) in the region.

Negative effects on populations of truly arctic species (polar bears, ringed seals, and bearded seals) are likely to result from climate warming. Polar bears and ringed seals depend on sea ice, and reductions in the extent and persistence of ice in the Beaufort Sea will almost certainly have negative effects on their populations (FWS 1995b). Climate change has already affected polar bears in western Hudson Bay, where bears hunt ringed seals on the sea ice from November to July and spend the open-water season on shore where they feed little. In a long-term study, Stirling and colleagues (1999) documented decreased body condition and reproductive performance in bears that correlated with a trend toward earlier breakup of sea ice in recent years. The earlier breakup gives bears a shorter feeding season. They are leaner when they come ashore, and they must fast longer. Many ringed seals give birth to and care for their pups on stable shore-fast ice, and changes in the extent and stability or the timing of breakup of the ice could reduce productivity (Smith and Harwood 2001). Because of the close predator-prey relationship between polar bears and ringed seals, decreases in ringed seal abundance can be expected to cause declines in polar bear populations (Stirling and Øritsland 1995).

How these independent factors might combine to influence populations cannot be predicted with current knowledge. If climate warming and substantial oil spills did not occur, cumulative effects on ringed seals and polar bears in the next 25 years would likely be minor and not accumulate.

Currently there are no research plans or studies that specifically address potential accumulating effects on polar bears or ringed seals off the North Slope. Unless such studies are designed, funded, and conducted over long periods (decades), it will be impossible to verify whether the effects occur, to measure their magnitude, or to explain their causes.

Findings

- Industrial activity in marine waters of the Beaufort Sea has been limited and sporadic and likely has not caused serious accumulating effects on ringed seals or polar bears.
- Careful mitigation can help to reduce the effects of North Slope oil and gas development and their accumulation, especially if there is no major oil spill. However, the

[1] The Liberty prospect is not being developed as of late 2002.

effects of full-scale industrial development of the waters off the North Slope would accumulate through displacement of polar bears and ringed seals from their habitats, increased mortality, and decreased reproductive success.

- A major Beaufort Sea oil spill would have major effects on polar bears and ringed seals.
- Climate warming at predicted rates in the Beaufort Sea region is likely to have serious consequences for ringed seals and polar bears, and those effects will accumulate with the effects of oil and gas activities in the region.
- Unless studies to address potential accumulation of effects on North Slope polar bears or ringed seals are designed, funded, and conducted over long periods, it will be impossible to verify whether such effects occur, to measure them, or to explain their causes.

CARIBOU

Introduction

The effects of North Slope industrial development on barren-ground caribou (*Rangifer tarandus granti*) herds have been contentious. Although much research has been conducted on caribou in the region, researchers have disagreed over the interpretation and relative importance of some data and how serious data gaps are. The disagreements are especially significant because caribou are nutritionally and culturally important to North Slope residents and because caribou are widely recognized as important symbols of the state and well-being of North Slope environments. For these reasons, the committee assembled information on caribou and evaluated conflicting interpretations of the information about how oil and gas development might have affected their population dynamics. The committee's consensus on effects to date, and projections of probable future effects, is the product of this careful analysis and deliberation.

Assessing the effects of oil and gas development on caribou is not straightforward because many factors other than oil and gas activities affect the sizes of North Slope caribou herds—weather, vegetation, disease, and predators, for example. Therefore, there is no steady baseline against which to identify and assess disturbance-induced changes. To evaluate the effects of petroleum development on caribou, the committee examined changes in distribution and habitat use, and evaluated the nutritional and reproductive implications of those changes and how they altered population dynamics.

Background

Caribou are ubiquitous on the North Slope. Four separate herds, ranging nearly 20-fold in size, are recognized on the basis of distinctly different calving grounds (Skoog 1968, Figure 8-2). The extent of seasonal migration varies with herd size (Bergerud 1979, Fancy et al. 1989, Skoog 1968). By far the largest is the Western Arctic Herd (WAH), estimated at 460,000 (in 2001). It calves in the Utukok uplands south of Barrow and summers throughout the North Slope and Brooks Range west of the Colville River, including most of the National Petroleum Reserve-Alaska. Wintering areas include both the western North Slope and the southern foothills of the Brooks Range. The annual range of the Teshekpuk Lake Herd (TLH), numbering 27,000 (in 1999), lies within the WAH summer range. Calving and summer ranges are in the coastal zone near Teshekpuk Lake; the winter range typically is confined to the coastal plain and nearby foothills. Estimated at 123,000 (in 2001), the Porcupine Caribou Herd (PCH) calves on the coastal plain and lower uplands in northeastern Alaska within the Arctic National Wildlife Refuge and adjacent Yukon Territory. During the summer, the PCH ranges throughout much of the eastern North Slope and Brooks Range; its wintering areas include the Ogilvie and Richardson mountains in western Canada and the southern Brooks Range in eastern Alaska. At 27,000 (in 2000), the Central Arctic Herd (CAH) is distributed primarily within state lands between the Colville and Canning rivers. CAH calving and summer ranges are on the coastal plain, and the winter range typically extends southward into the northern foothills of the Brooks Range. During the past 27 years, the size of the PCH has been nearly constant; the other three herds have increased substantially (Figure 8-3).

Central Arctic Herd

For the past 50 or 60 years, all four herds (Figure 8-2) have been exposed to oil and gas exploration activity, but only the CAH has been in regular and direct contact with surface development related to oil production and transport. Its calving ground and summer range lie within the oil-field region near Prudhoe Bay; its autumn, winter, and spring ranges encompass the Dalton Highway (also called the Haul Road) and the area around the Trans-Alaska Pipeline (Cameron and Whitten 1979b). The CAH has increased from around 5,000 animals in the late 1970s to its current (2000) size of 27,000 (Figure 8-3).

Parturient females, along with most nonparturient females and yearlings, arrive on the coastal calving ground in mid-May (Gavin 1978, Smith et al. 1994). The exact timing depends on patterns of snowfall and snowmelt (Cameron et al. 1992, Gavin 1978). Most calving occurs within 50 km (31 mi) of the Beaufort Sea (Whitten and Cameron 1985, Wolfe 2000). Virtually all calves are born between late May and early June (Cameron et al. 1993) within two or three calving concentration areas (Whitten and Cameron 1985, Wolfe 2000). At the landscape level, selection and repeated use of a calving ground is probably related to both the distribution of predators, which are less abundant on the coastal plain (Rausch 1953; Reynolds 1979; Shideler and Hechtel 2000; Stephenson 1979; Young et al. 1992, 2002) and the likelihood of favorable foraging conditions (Griffith et al.

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FIVE-NATION CONFERENCE ON POLAR BEARS
SCHEDULED FOR SEPTEMBER IN ALASKA

In a joint announcement with United States Senator E. L. "Bob" Bartlett of Alaska, Secretary of the Interior Stewart L. Udall said today that a five-nation meeting of scientists concerned with polar bear conservation will be held at the University of Alaska, Fairbanks, September 6-11, 1965.

Secretary Udall said Senator Bartlett has led in awakening public interest in the preservation of the polar bear and has been closely concerned with planning the international conference.

Formal invitations to the Fairbanks meeting have been sent to Canada, Norway, Denmark and the Soviet Union. Certain private conservation organizations will be asked to send observers.

Secretary Udall said much remains to be learned about polar bears and that the scientists from the five nations will study factors concerning population, distribution, exploitation, reproduction, danger of extinction, and related matters. He said the polar bear's range has contracted considerably since 1930, but data to support stories circulated that it is becoming a rare animal are not definitive.

"It is time the scientists got together to determine how much fact and fancy there are in the various reports," Secretary Udall commented.

Most of the United States research on polar bears has been done by State of Alaska scientists. These scientists will be among those participating in the international meeting. Secretary Udall pointed out that Alaska is the only State where polar bears are found, and the State is vitally concerned with proper management of the resource.

Secretary Udall said all available scientific information will be pooled and then distributed to governments concerned to determine future action and policies toward polar bear conservation. The Fairbanks meeting is expected to propose programs for collecting needed scientific data and for international collaboration in polar bear research vital to proper conservation.

"It is particularly fitting that such a conference take place during the International Cooperation Year (ICY) now being observed around the world," Secretary Udall added. "It is in such forums that experts from many lands can discuss conservation problems of mutual concern and establish the foundations for future actions that can benefit all men."

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